KINGDOM OF THAILAND
MINISTRY OF AGRICULTURE AND COOPERATIVES
ROYAL IRRIGATION DEPARTMENT

FEASIBILITY STUDY ON THE SAKAE KRANG RIVER BASIN IRRIGATION PROJECT

ANNEX

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HYDROLOGY

1. MAE WONG BASIN HYDROLOGY

1.1 Climate

The Mae Wong river basin is characterized by two pronounced seasons, one dry from November to April, the other wet during the rest of the year. Aerial rainfall distribution in the basin affected by the topography is relatively small. Average annual rainfall ranges from 1,300 mm in the western watershed to 1,100 mm in the eastern plain of the basin, of which about 85% is concentrated during wet season. September is generally the month of heaviest precipitation during the prevailing southwest monsoon season.

The temperature differentials within the basin are relatively small. Based on the data at Nakhon Sawan, mean temperature is about 28.5°C. The coolest month is December with the mean monthly temperature of 25.2°C while the hottest one is April with 31.9°C.

The prevailing wind direction over the basin is south and relatively constant during the months of February through October. The average relative humidity varies from 61% to 82% at average annual value is 70% at Nakhon Sawan. Mean annual pan evaporation is 2,089 mm with monthly variations of 260 mm in April and 128 mm in September.

Meteorological station under the Ministry of Communications is located at Nakhon Sawan. Among hydrological gaging stations under the RID within the Mae Wong river basin, the station at CT-5A, furnishes meteorological data of temperature, evaporation and wind speed. These data are summarized in Table I-1 and Table I-2.

1.2 Rainfall

1.2.1 Rainfall records

Rainfall data are collected from 50 gaging stations located between latitude from 15°-0' N to 16°-15' N and longitude from 99°-0' E to 100°-15' E to cover the whole Sakae Krang river basin. All these stations are operated by RID. Average monthly rainfall is listed in Table I-3. As shown in the Fig. I-1, the distribution of gaging stations is not even. Many stations are located along the Chao Phraya river and downstream of the Sakae Krang Basin. The rainfall stations located within the Mae Wong river basin are only 4 in number, and no rainfall station is located in the watershed of the Upper Mae Wong dam. Nearest station is CT-5A, about 14 km downstream.

Periods of observation and code number of gaging station are shown in Fig. I-2. Rainfall records are available from 1920 to 1983.

1.2.2 Rainfall characteristics

(1) Average monthly rainfall

Average monthly rainfalls for the 4 stations located within the Mae Wong river basin are as follows.

(mm)

Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
71	163	128	132	179	262	150	40	6	10	12	25

Note: 4 stations are 12081, 26072, 26270, 69062

Average annual rainfall of above stations is 1,180 mm. Seasonal fluctuation of rainfall is very large and average monthly rainfall ranges from 6 mm in December to 262 mm in September.

(2) Aerial distribution of rainfall

Aerial distribution of annual rainfall amount is not remarkable. Within the Mae Wong river basin, distribution is almost even varying from 1,120 mm/year at downstream to 1,320 mm/year at upstream area.

1.2.3 Correlation

Among 50 rainfall gaging stations, 22 stations are selected for the correlation analysis from the standpoint that the stations are located within or adjacent to the Sakae Krang river basin and have longer observation period with shorter data missing period. Results of correlation calculation on the monthly rainfall are shown in Table I-4. Most of the stations show correlation rate more than 70%. There is no station which shows extremely low or high correlation rate. It is considered that the rainfall pattern is sufficiently even and rain gauge record is highly reliable.

1.2.4 Daily rainfall probability

Selecting 19 rainfall gauging stations of having more than 30 years complete observation data, the maximum daily rainfall probability was calculated by the Iwai method and the results are shown in Table I-5 for each stations.

The maximum value of daily rainfall intensity is determined as follows.

Return Period (1/year)	Rainfall Intensity (mm/day)	Rainfall Station (Code No.)
1/5	141.7	69052
1/10	166.4	"
1/20	189.0	"
1/50	217.3	"
1/100	238.0	"
1/200	260.4	12042
1/500	295.7	"
1/1000	323.0	"

Rainfall stations of 69052 and 12042 are located at southern and northern outside of the Sakae Krang basin, respectively.

The maximum daily rainfall intensity of 303.3 mm/day was recorded at rainfall gauging station of 04170 on Sep. 28, 1956. This value corresponds to the return period of 1/500 years.

1.3 Streamflow

1.3.1 Streamflow records

There are seven gauging stations within the Sakae Krang river basin. The locations and periods of runoff observation are shown in Fig. I-1 and Fig. I-3. The stations located within the Mae Wong river basin are CT-5A, CT-5, and CT-4. The station CT-5A on the Mae Wong river is equipped recently with the automatic water level recorder which is being operated by IRD. Other stations are equipped with the staff gauges and operated by RID. All these stations are rated by current meter measurements, where river stage versus discharges are plotted to establish rating curves every year. These rating curves are used to convert daily gauge height readings to daily discharges. Record of monthly runoff at CT-5A is summarized in Table I-6.

(1) Reliability of runoff records

Double mass curves of the recorded river runoff and rainfall are shown in Fig. I-4. The curve for the station of CT-4 shows large fluctuation of runoff rate, which indicates the disturbance of irrigation water intake at upstream of this station. The runoff data at station of CT-5A is considered fairly accurate for the watershed runoff analysis since it shows relatively constant runoff rate in the double mass curve over the observation period.

1.3.2 Streamflow characteristics

Streamflow in the Mae Wong river basin is characterized by large fluctuation of runoff amount between dry and wet seasons and by small runoff rates throughout the year.

The average annual runoff rate at CT-5A during observation period, 1969-1983, is about 29%. Based on the results of runoff analysis, the streamflow characteristics are presented in Chapter 4 from the print of water resources.

1.4 Sedimentation

Sediment load is one of the major factors to define the reservoir dimension. Sediment inflow is usually calculated from bed load and suspended load. As for the bed load inflow estimation, samples on the gradation analysis on the river bed material were collected at Upper Mae Wong damsite. Conditions and assumption for bed load calculations are as follows:

1. Analysis point : Upper Mae Wong damsite
   Drainage area : 612 km^2
2. Gradation analysis : 3 samples
3. River cross section is assumed as rectangular shape. Relation of river width and water depth is as follows.

Water depth (m)	River width (m)
0.5	10
1.0	14.5
1.5	20
2.0	23
2.5	26.5
3.0	29.5

4. River roughness coefficient : n = 0.05 - 0.09
5. River discharge is calculated by Manning formula.
6. Specific gravity of bed load : 2.68
7. Average grain size : 0.97 mm

8. Formula applied : Sato, Kikkawa, Ashida formula

$$qB \cdot \left(\frac{\sigma}{\rho} - 1\right) \cdot g = U*^3 \cdot \phi \cdot f \cdot \left(\frac{\tau o}{\tau c}\right)$$

Where, qB: bed load per unit river width per unit hour, expressed by volume (m^3/sec/m)

τc: critical tractive force

$\phi = 0.623 \left(\frac{1}{40n}\right)^{3.5}$ for $n \leq 0.025$

$\phi = 0.623$ for $n \geq 0.025$

Based on the gradation analysis and the calculation of qB (m^3/sec/m), the relation between bed load QB (t/day) and the corresponding average river discharge QB (m^3/sec) is plotted in log-lot scale as shown in Fig. I-5 and it is expressed by following formula.

$$QB = 60.3 \cdot Q^{1.05}$$

Where, QB: Bed load t/day

Q: Average river discharge m^3/sec

As for the suspended load, 49 samples of suspended load are available at CT-5A during June, October and November, 1983. Same procedures as applied for the bed load were taken and the relation between the suspended load and the river runoff discharge is expressed as follows.

$$Qs = 1.34\, Q^{1.83}$$

Where, Qs: Suspended load t/day

Q: Average river discharge m^3/sec

In order to calculate the average total sediment inflow, the year of 1978 is selected as the representative average year from 1969 to 1983. Applying daily discharge at CT-5A in 1978, the sediment inflow per year is calculated.

Bed load	182, 974 t	112 m^3/km^2/yr
Suspended load	178,951 t	71 m^3/km^2/yr
Total		183 m^3/km^2/yr

In application of this result to the design of reservoir, appropriate safety measurement should be considered.

1.5 Water Quality

Samples for water quality analysis were taken at 21 points along the Mae Wong river including the proposed dam site and irrigation canals.

According to the "United State Department of Agriculture", the irrigation water quality is classified into four grades with respect to the sodium hazard (S1-S4) depending on the sodium-absorption ratio (SAR) and the salinity hazard (C1-C4) depending on the electric conductivity (EC). Results of water quality analysis are summarized in Table 1-7 and locations of sampling are shown in Fig. I-12.

Nineteen (19) samples are classified into C1-S1 class and two (2) samples are C2-S1 class. Based on this water quality analysis, the river water is all within the tolerable limit and suitable for irrigation. In fact, no adverse effects have been reported by using the river water for irrigation.

As for the groundwater quality, the preliminary study was conducted by RID from 1973 to 1978 for the downstream area of the Sakae Krang river basin including a part of the Mae Wong river basin. In this study, most of the water samples obtained from the bore holes are found suitable for irrigation. However, 18 samples out of 53 were found unsuitable because of very high electric conductivity and sodium absorption ratio. Certain correlations or tendency on the depth or locations among these samples of unsuitable quality is not determinable as the number of samples are not sufficient. It is necessary to continue the observation on the seasonal variation of groundwater quality to clarify the potential productivity for irrigation.

2. RUNOFF ANALYSIS

2.1 Methodology for Analysis

Observation periods of river runoff are limited only for 15 years at CT-5A within the Mae Wong river basin. Required runoff records for the water balance analysis are for about 30 years or more. Longterm runoff analysis is necessary to generate the streamflow from rainfall records.

(1) Runoff model

Correlation analysis was firstly tried between river runoff and rainfall records, but did not show applicable results. Because the analysis does not meet with the seasonal base flow fluctuation especially during dry season. Tank model analysis is then executed.

(2) Runoff record

The runoff records at CT-5A were utilized for generation of runoff model at the Mae Wong river, since runoff records at this station show high reliability based on the double mass curve analysis.

(3) Rainfall record

As for the rainfall to be applied for the model and to generate the longterm runoff, the Thiesen polygon method was used among 4 stations of 63042, 12081 (CT-5A), 26281 (CT-7) and 69121/19092 (CT-9). The distances between these stations are so far that the polygon becomes too large to devide the drainage area of Mae Wong river and the polygon components were formed by only two rainfall station of 63042 and 12081.

Tank model was analysed under the combination of following runoff and rainfall records. Basic unit period for analysis was selected at 10 days.

River	Runoff Record	Rainfall Record	Drainage Area
Mae Wong	CT-5A	63042/12081	936 km^2

2.2 Runoff Model

Tank model is composed of a series of storage tanks and runoff outlets at each tanks. For the analysis of the Mae Wong river, a model of four storage tanks was introduced. Second tank has no runoff outlets but works to give lag time in the runoff calculation.

Simulation calculations were conducted by computer until obtaining adequate accuracy between the observed streamflow records and calculated runoff. The results of calculation and determined model are shown in Table I-8, Fig. I-6 and Fig. I-7. In the course of tank model calculation, the evaporation data was adopted from the observation record at Nakhon Sawan.

2.3 Streamflow Generation

(1) Rainfall generation

In the absence of longterm runoff records required for the reservoir operation study, it is necessary to generate the streamflow by applying tank model. Prior to the streamflow generation, the rainfalls have to be generated for the period of no rainfall observation. Based on the results of rainfall correlation analysis, following stations were selected to supplement the deficit of data. Simulated rainfalls are shown in Table I-9.

Rainfall Station	Supplemental Station	Correlation Rate	Tank Model
63042	69022	0.68	Mae Wong River
12081	26072	0.79	Mae Wong River

(2) Streamflow generation

Streamflow generation was conducted for the period of 30 years from 1954 to 1983. The results of simulation are shown in Table I-10.

3. FLOOD ANALYSIS

3.1 Methodology for Analysis

Purposes of flood analysis are to define the design flood for dam spillway and to clarify the effect of flood control by reservoir.

A large volume of water behind a dam could cause considerable damage to property and loss of life, if the impounded water is suddenly released in case of failure of the dam. Flood studies therefore, particularly the selection of flow design flood to size the spillway and surcharge storage is of importance in the design of large dams.

The derivation of the inflow design flood for the proposed Upper Mae Wong dam consists of the determination of a design storm estimated from enveloping observed maximum flood for various drainage area, rational formula adopted for probable point rainfall in the region and from the unit hydrograph study. Comparing the amount of flood derived from the above three methods, the maximum flood value is applied as the spillway design flood.

3.2 Design Flood for Dam

3.2.1 Creager envelope

The annual maximum flood discharge records were collected from 8 gauging stations in the Sakae Krang river basin and 60 gauging stations in 6 river basins in the Central Chao Phraya Plain. These rivers are the Yom, the Nam, the Mae Klong, the Ping, the Pasak and the Chao Phraya rivers. The collected data are listed in Table I-11.

The specific discharges ($m^3/sec/km^2$) of the maximum floods for each station versus drainage area are plotted in log-log scale as shown in Fig. I-8. The envelope to cover the whole flood points gives the Creager's envelope expressed as follows.

$$q = C \times A^{(A^{-0.04} - 1)}$$

Where, q: Specific discharge ($m^3/sec/km^2$)
C: Coefficient 9.0
A: Drainage area (km^2)

Evaluating from the range of floods collected as shwon in Fig. I-8, the above curve will be adoptable for the drainage area between 300 km^2 and 10,000 km^2. The design flood calculated by this formula for Upper Mae Wong damsite is 1.290 m^3/sec with specific discharge of 2.11 $m^3/sec/km^2$.

3.2.2 Flood probability

Flood probability was also analysed for annual maximum flood recorded in the Sakae Krang Basin. Among gauging stations in the basin, CT-7 gauging station having drainage area of 403 km^2 gives maximum flood scale for each return period. The number of samples utilized for probability calculation is only 7 at CT-7 and as many as 14 at CT-5A, therefore, the accuracy will be limited within for shorter return period. The results of probability calculations are shown in Table I-12. Taking the results on CT-7 from Table I-12, the calculated floods at the Upper Mae Wong dam site with different return periods are shown below.

(Unit: m^3/sec)

Dam	Return Period		
	1/10	1/100	1/200
Upper Mae Wong	480	1,010	1,210

3.2.3 Rational formula

Rational formula was applied to derive a peak flood discharge from the rainfall intensity with different probability.

$$q = \frac{1}{3.6} \times f \times Re$$

where, q: Specific discharge ($m^3/sec/km^2$)
f: Runoff rate 0.8
Re: Rainfall intensity within concentration time (mm/hr)

$$Re = \frac{R24}{24} \times \left(\frac{24}{Tp}\right)^n$$

where, R24: daily rainfall (mm/day)
Tp: Flood concentration time (hr)
n: Coefficient

$$Tp = C \times A^{0.22} \times Re^{-0.35}$$

where, C: Coefficient 800
A: Drainage area (km^2)

Daily rainfall intensity R24 with different probability was obtained from probability calculations of the 19 raingauge stations having more than 30 years of records out of 50 gauging stations in and around the Sakae Krang river basin. The results are presented in Table I-5. Coefficient C and n are obtained from hourly and daily rainfall and river discharge records converted from automatic water level gaugings at CT-5A, as shown in Fig. I-9 and Fig. I-10. Probable floods calculated by these formulae are summarized in Table I-13. Selecting several representative return periods from the Table I-13, the calculated floods by the rational formula are summarized as follows:

(Unit: m^3/sec)

Dam	Return Period 1/10	1/100	1/200
Upper Mae Wong	857	1,334	1,481

3.2.4 Unit hydrograph

(1) Hourly data

Hourly rainfall and river runoff data are available from automatic gauging recorders equipped at CT-5A station. Analysing these hourly data, following 5 flood patterns are selected to choose greater rainfall intensity and larger total rainfall.

No.	Flood	Peak Rainfall (mm/hr)	Total Rainfall (mm)	Runoff Height (mm)
1.	Jul. 7, 1980	43.4	43.4	0.5
2.	Jul. 31 - Aug. 1, 1980	58.0	63.1	1.6
3.	Aug. 8 - 9, 1981	40.0	72.2	0.5
4.	Nov. 7 - 8, 1981	29.0	164.7	112.0
5.	Oct. 11 - 12, 1983	23.6	82.8	139.0

Among these flood patterns, the flood on Nov. 7-8, 1981 shows good correlation between rainfall and runoff pattern and has the largest total rainfall. For the analysis of unit hydrograph, therefore, the representative flood pattern was selected to be of Nov. 7-8, 1981 flood.

(2) Formula

Following unit hydrograph formulae derived by Dr. Nakayasu are adopted for the analysis,

$$Qp = \frac{0.2778 \times A \times Ro}{0.3 \times tp \times tk}$$

$$\frac{Q}{Qp} = \left(\frac{t}{tp}\right)^{2.4} \qquad \text{for } t = 0 \text{ to } t = tp$$

$$\frac{Q}{Qp} = 0.3^{(t - tp)/tk} \qquad \text{for } t = tp \text{ to } t = tp + tk$$

$$\frac{Q}{0.3 \times Qp} = 0.3^{[t - (tp + tk)]/(1.5 + tk)}$$

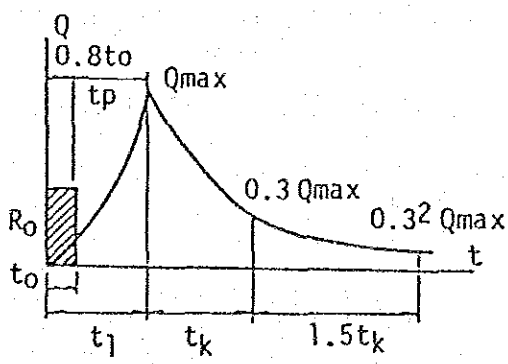
for t = tp + tk to t = tp + 2.5 = tk

$$\frac{Q}{0.3^2 \times Qp} = 0.3^{[t - (tp + tk + 1.5 \times tk)]/(2.0 \times tk)}$$

for more than t = tp + 2.5 x tk

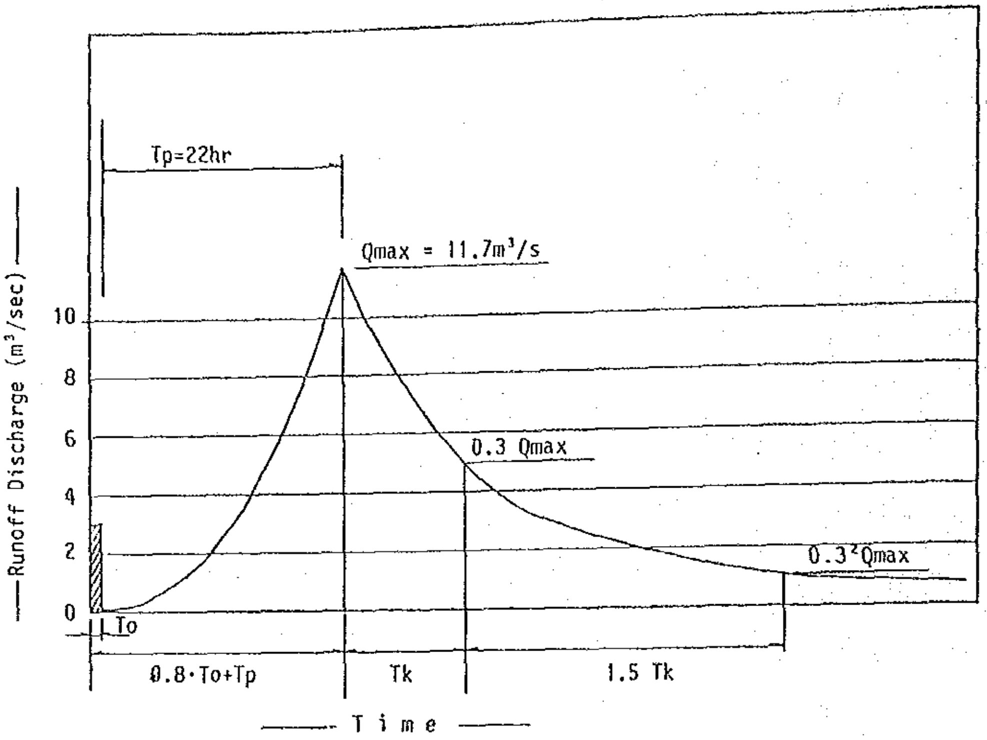
tk = TG x a

where,
- A: Drainage area (km^2)
- Ro: Unit rain (mm) for the unit duration (hr)
- tp: Basic lag (hr) from the beginning of rain to the peak of unit hydrograph
- tk: Period (hr) from the peak to the time of Q = 0.3 x Qp
- TG: Lag time (hr)
- a: Coefficient



(3) Unit hydrograph

Based on the relations between peak flow and peak rainfall intensity on the hourly streamflow and rainfall data, the lag time TG is assumed at 22 hr and coefficient a is taken at 0.7. Culculated flood curve and recorded flood on Nov. 7-8, 1981 are shown in Fig. I-11 and Table I-14. The obtained unit hydrograph is as follows.



(4) Calculation of 200-year flood

For the calculation of 200-year flood by unit hydrograph, daily rainfall intensity of 260 mm/day is applied as it has 200-year probability as shown in Table I-5. The daily rainfall of 260 mm/day is then distributed into hourly intensity to form hourly rainfall pattern in accordance with the following 2 cases.

Case 1: Proportionally distributed to the recorded rainfall pattern on Nov. 7-8, 1981

Case 2: Hourly rainfall pattern having peak rainfall intensity at the end of rainfall.

Hourly Rainfall Distribution

(mm/hr)

Case	1	2	3	4	5	6	7	8	9	10	11	12
Nov. 7-8	9.2	4.8	11.4	0	0	1.2	3.0	0	0	0	0	-
1	15.8	8.2	19.2	17.8	0	0	2.1	5.1	0	0	0	4.6
2	7.2	7.3	7.4	7.7	7.8	8.0	8.3	8.5	8.7	9.2	9.5	9.8
Case	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Nov. 7-8	13.6	16.1	1.8	29.0	5.2	3.8	1.8	6.2	10.8	6.8	4.5	9.5
1	23.3	27.7	3.1	49.8	8.9	6.5	3.1	10.6	18.5	11.7	7.7	16.3
2	10.6	11.2	11.8	13.8	15.5	18.5	31.9	12.6	10.2	8.9	8.1	7.5

Flood Calculations are shown in Table I-15 and Fig. I-13. The results are summarized as follows.

Case	Peak Flood ($m^3/sec/km^2$)
1	1.49
2	1.50

3.2.5 Design flood for dam

(1) Spillway design flood

Spillway design flood is determined by selecting maximum peak flood scale among several floods derived from various methods. As for the flood probability, 200-year return period is adopted. Comparison of flood scale is made in terms of specific discharge ($m^3/sec/km^2$) as follows. Flood derived from ractional formula gives the maximum flood scale.

Dam	Drainage Area (km^2)	Peak Flood ($m^3/sec/km^2$)			
		(1)*	(2)*	(3)*	(4)*
Upper Mae Wong		2.11	1.98	2.44	1.50

Note: (1)* Creager envelope
(2)* Flood probability (200-year) at CT-7
(3)* Rational formula (200-year)
(4)* Unit hydrograph

(a) Recorded maximum daily rainfalll

The daily rainfall intensity applied for the calculation of 200-year flood by rational formula is 260 mm/day which is derived from probability calculation on the raingauge station 12042. The recorded maximum daily rainfall intensity is 303 mm/day at raingauge station 04170 which has 21 years of observation period and is located outside of the Sakae Krang basin, about 120 km away from the Upper Mae Wong Dam site. The value of 303 mm/day is equivalent to the rainfall probability scale of about 500-year return period. The flood derived from 303 mm/day rainfall intensity by rational formula is as follows.

Flood by Recorded Maximum Rainfall

Dam	A (km^2)	Re (mm/hr)	q ($m^3/sec/km^2$)
Upper Mae Wong	612	12.9	2.87

(b) Spillway design flood for fill-type dam

In case of fill-type dam, the flood over topping from the dam crest is considered more serious than in case of concrete dam. The spillway design flood is taken to be 20% increased from the 200-year flood obtained by rational formula. The spillway design flood is then determined as follows. Design flood of 1.770 m^3/sec corresponds to the flood scale of more than 500-year return period.

	Drainage Area (km^2)	Specific Discharge (1) ($m^3/sec/km^2$)	(2)	(3)	Spillway Design Flood (m^3/sec)
Upper Mae Wong	612	2.87	2.44	2.90	1,770

where, (1): Derived from 303 mm/day
(2): Derived from 260 mm/day
(3): (2) x 1.2

3.3 Flood Control

3.3.1 Flood damage

Data on the flood damage caused by the floods in 1981 and 1983 were obtained from provincial offices at Nakhon Sawan and Uthai Thani and are summarized in Tables I-16 and I-17. In Nakhon Sawan province, damaged sub-districts are Mae Lae, Huai Nam Hom, Wang Sarn and Muban Lat Yao in case of November, 1981 flood. Four persons were lost in Lan Sak and Muban Uthai Thani District in 1981. Five persons were lost in Sawang Arom, lan Sak and Thap Than District in 1983. The number of damaged houses are 58 in 1981 and 134 in 1983.

In case of November, 1981 flood, 310,000 rais of farm lands (7% of the total area of Uthai Thani Province) were flooded and 54,500 rais of them were inundated. In case of 1983 floods, 18,000 rais of farm land were inundated. Public facilities such as roads, bridges, weirs, government offices, temples, etc. were also damaged.

Although every district gets flood damages, three districts (Lan Sak, Sawang Arom and Thap Than) seem to have heavier damages. They are surrounded by Khlong Pho and Thap Salao Rivers.

3.3.2 Flood control

(1) General

Flood control is not primary purpose for the Project, however, it is realized that incidental flood controle could be attained from the operation of the reservoir especially with such floods which occur in the early part of wet season. Based on the reservoir operation simulation discussed in Annex III, flood control effects were studied through the comparison of with reservoir and without reservoir conditions.

The results of study are summarized in Table I-18. Simulation of reservoir operation from 1954 to 1983 shows that there is no spillout from the reservoir for 16 years out of 29 years except for irrigation purpose. When the reservoir is at full storage level, the spillout occurs, however, the annual peak flood scales are considerably reduced as it is shown in the comparison of the annual maximum flood for the conditions of with and without reservoir. These are summarized as follows.

Dam	Ave. Annual Inflow (MCM/yr)	Regulated by Dam (MCM/yr)	Regulated Percent (%)	Ave. Max. Flood without Dam (m^3/sec)	Ave. Max. Flood with Dam (m^3/sec)	Reduced Percent (%)
Upper Mae Wong	209.5	162.6	78	41.2	15.4	63

(2) Flood routing

The flood surcharge level of the reservoir was determined at elevation 207.5 m from the design overflow depth of spillway crest, since the dam has no flood control reservoir capacity. However, the reservoir capacity between the full water level (spillway crest level) of 204.5 m and designed flood surcharge level of 207.5 m is sufficiently large at 62 MCM which incidentally produces flood control effect.

Following flood scales were adopted for reservoir routing study with the flood inflow pattern analysed by unit hydrograph.

Flood Scale	Peak Flood
1. Spillway design flood	1,770 m^3/sec
2. 100-year return period	1,340
3. 50-year return period	1,200
4. 10-year return period	860

The results of flood routing calculation are shown in Fig. I-14, and summarized below.

Peak Flood without Reservoir	Peak Flood with reservoir	Reduction Ratio
1,770 m^3/sec	1,560 m^3/sec	12%
1,340	1,130	16
1,200	990	18
860	650	24

Flood Scale	Flood Volume without Reservoir	Retaining Volume with Reservoir	Reduction Ratio
Design flood	187 MCM/3 days	28 MCM/3 days	15%
100-year	141	25	18
50-year	127	24	19
10-year	91	20	22

It was also confirmed by the flood routing that the flood retaining capacity of the reservoir between full water level and designed high water level will allow to receive and pass the flood scale of up to 2,000 m^3/sec equivalent to the return period of 1,000-year.

4. WATER RESOURCES

4.1 Available Streamflow

The average annual discharge at upstream watershed of the Mae Wong river (CT-5A) was estimated from the actual runoff record and generated streamflow by tank model. The runoff discharge is summarized as follows.

Result of Runoff Analysis (1954-1983)

River	Station	Average Basin Rainfall (mm)	Average Annual Discharge (MCM/km^2)	Average Runoff Rate (%)
Mae Wong River	CT-5A	1,339.1	0.360	26.9

The Mae Wong river is known to be effluent streams which continues to flow even during extremely dry periods. The upper portion of the Mae Wong river watershed is extensively forested while the watershed forest of other rivers are relatively thin.

Monthly river runoff simulated by runoff model is summarized as follows.

Average Month River Runoff (1954-1983)

(Unit: 1,000 m^3/km^2)

River	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Mae Wong	2.3	8.5	15.4	18.6	37.6	85.1	125.0	45.0	12.0	6.3	3.8	2.8

The river runoff is characterized by long low flow period from December to July. Reliable amount of water resource supplied by the river is limited only during four months from August to November. About 80% of total annual runoff occurs during these months.

Table I-1 METEOROLOGICAL DATA FOR THE PERIOD 1951-1980 AT NAKHON SAWAN

Lat 15-48 N
Long 100-10 E

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Mean	25.6	28.3	30.7	31.9	30.6	29.6	29.0	28.5	28.0	27.9	26.7	25.2	28.5
Mean Max	32.2	34.5	36.7	37.9	36.1	34.5	33.8	33.1	32.2	32.0	31.5	31.1	33.8
Mean Min	17.7	21.0	23.7	25.3	25.1	24.7	24.3	24.1	23.9	23.5	21.0	18.2	22.7
Ext Max	37.0	39.8	41.2	42.5	42.7	41.0	38.9	37.8	36.3	35.9	35.7	35.8	42.7
Ext Min	6.1	12.0	14.2	17.0	20.3	21.4	20.9	20.9	20.4	18.4	11.9	8.2	6.1
Relative Humidity (%)													
Mean	63.0	62.0	61.0	61.0	70.0	74.0	75.0	78.0	82.0	80.0	73.0	67.0	70.0
Mean Max	87.3	86.9	87.3	86.5	89.1	90.5	91.5	92.9	95.5	94.7	92.4	89.9	90.4
Mean Min	41.3	40.3	39.1	40.8	51.2	56.6	58.4	62.0	66.4	63.3	53.9	45.9	51.6
Dew-Point (°C)													
Mean	17.1	19.3	21.2	22.7	23.8	23.9	23.8	24.0	24.4	23.7	20.8	17.9	21.9
Evaporation (mm)													
Mean - Pan	150.6	174.9	232.8	260.3	218.9	184.1	174.3	153.2	127.7	138.8	132.8	140.5	2,088.9
Wind (knots)													
Prevailing wind	E	S	S	S	S	S	S	S	S	S	E	N	-
Mean wind speed	3.7	4.8	6.3	6.4	5.4	5.5	5.0	4.4	3.2	3.0	3.4	3.5	-
Max wind speed	33NE	58S	62N	60N	70S	50S	52S	45SSW	65N	54NE	27NW	27E	78S
Sunshine Duration (hr)													
Mean	264.1	242.9	249.0	259.2	243.0	186.2	174.2	169.0	158.7	228.6	256.8	275.5	2,707.2
Cloundiness (0-8)													
Mean	3.0	3.3	3.3	4.0	5.6	6.4	6.7	6.9	6.6	5.4	4.2	3.4	4.9

Table I-2 METEOROLOGICAL DATA AT CT5-A

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Mean													
CT-5A (1969-1983)	20.6	22.3	24.9	27.0	26.9	26.1	26.3	24.9	25.5	24.8	22.9	21.0	24.5
Wind (km/hr)													
Mean Wind Speed													
CT-5A (1973-1983)	1.08	1.46	1.67	2.00	1.91	1.43	1.30	1.06	0.98	0.90	0.83	0.96	1.30
Evaporation (mm)													
Mean - Pan													
CT-5A (1973-1983)	83.7	89.5	117.3	130.8	120.3	93.4	91.8	75.4	80.7	79.8	75.6	79.2	1,117.5

Table I-3 AVERAGE MONTHLY RAINFALL AND MAXIMUM DAILY RAINFALL (1/3)

Code	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Maximum Daily Rainfall
04300	27.9	98.8	85.9	90.6	123.5	231.0	112.2	16.9	6.0	0.4	8.7	15.5	784.1	167.2 (Sep.18 1972)
04310	31.0	107.6	102.8	100.6	133.6	233.6	89.2	27.5	6.3	0	18.7	11.8	814.3	163.8 (Sep. 18 1972)
04320	48.0	133.8	86.8	123.2	157.4	259.3	144.9	36.3	4.3	4.9	8.3	32.6	1,042.6	175.0 (May 5 1976)
04330	57.9	133.8	102.7	114.5	157.1	255.1	130.6	38.5	7.7	7.2	16.2	29.8	1,051.0	150.4 (Oct.6 1986)
04340	28.9	125.4	85.2	154.0	120.9	255.3	126.5	22.6	1.8	0.3	5.1	8.2	920.3	207.2 (May 6 1976)
04361	38.5	125.4	90.2	109.5	125.6	232.7	130.2	32.3	3.8	4.3	12.5	24.8	935.7	127.8 (Sep. 21 1965)
12022	35.8	134.1	136.1	126.5	142.8	239.0	129.8	28.7	3.1	6.5	11.9	12.9	991.4	150.7 (May 5 1976)
12042	66.1	169.4	162.2	166.9	178.1	168.0	138.1	35.6	4.2	6.6	13.0	23.7	1,222.7	209.4 (Sep. 29 1978)
12081	57.0	193.3	140.0	145.1	178.1	321.3	169.9	38.4	8.3	12.9	9.1	39.4	1,320.6	135.6 (Jul. 3 1970)
12091	48.2	177.5	168.8	149.8	139.5	275.2	95.3	69.7	0	0	10.4	12.4	1,164.7	178.0 (May 21 1980)
13112	111.9	200.4	97.7	102.9	161.9	220.6	144.5	33.0	3.9	4.6	20.9	54.2	1,044.5	141.5 (Nov. 12 1967)
26013	70.0	135.8	138.7	153.0	184.5	261.5	146.4	20.7	4.9	8.5	21.3	26.7	1,166.2	161.1 (Sep. 6 1931)
26042	52.1	112.9	102.5	127.6	173.1	239.2	140.2	24.2	2.6	6.8	12.9	23.6	1,123.4	176.4 (Sep. 16 1953)
26052	86.4	123.8	122.4	143.1	166.5	247.1	148.9	29.3	2.9	5.0	17.0	26.5	1,089.9	186.0 (Apr. 28 1947)
26062	50.4	115.9	116.3	120.9	162.9	237.7	97.5	22.4	2.2	7.3	11.2	18.8	1,073.5	184.0 (Sep. 13 1938)
26072	67.4	149.3	126.5	139.7	172.0	247.1	171.9	31.9	6.5	10.5	21.0	28.8	1,131.4	254.0 (Oct.24 1952)
26170	45.1	121.9	96.7	123.9	176.9	241.2	120.9	40.9	3.1	8.8	6.4	29.3	1,015.1	163.5 (Oct. 6 1966)

Table I-3 AVERAGE MONTHLY RAINFALL AND MAXIMUM DAILY RAINFALL (2/3)

Code	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Maximum Daily Rainfall
26270	91.5	171.3	117.8	107.4	184.6	211.0	107.2	49.1	3.3	9.4	8.1	9.7	1,063.0	88.7 (Nov. 7 1981)
26281	37.1	215.4	121.7	124.9	156.7	263.5	177.5	95.4	10.4	0.6	6.8	25.4	1,193.7	270.0 (Nov. 7 1981)
63042	78.0	142.9	177.7	240.1	251.1	244.9	115.5	27.9	6.7	6.0	12.4	36.7	1,378.6	123.0 (Mar. 31 1941)
69012	69.5	129.6	125.0	135.3	164.2	279.9	165.6	35.2	5.6	4.5	12.5	27.7	1,154.0	208.7 (Oct. 6 1966)
69022	70.6	147.8	115.4	147.4	184.9	310.5	140.7	41.6	4.9	7.2	10.8	38.0	1,228.4	148.9 (Oct. 20 1961)
69032	64.0	116.8	118.1	121.3	149.8	263.9	136.3	27.3	3.7	6.2	10.7	25.3	1,059.7	210.0 (Apr. 13 1928)
69042	70.5	154.8	149.5	148.2	196.8	317.7	191.6	38.3	5.6	9.7	17.5	34.7	1,337.1	252.5 (Aug. 31 1924)
69052	141.9	214.5	193.9	191.1	176.5	397.2	248.4	55.3	21.5	4.9	14.2	68.5	1,814.5	190.0 (Oct. 1 1963)
69062	76.3	139.9	127.8	135.0	182.3	269.0	152.4	42.3	5.6	5.2	9.1	21.7	1,166.1	121.6 (Sep. 21 1978)
69090	71.8	205.9	189.2	108.0	165.8	349.0	226.1	50.7	14.6	26.0	23.7	55.3	1,440.3	121.6 (May 15 1970)
69110	75.8	177.4	138.0	127.5	205.6	236.0	105.5	23.4	1.8	0.6	11.9	35.7	1,208.2	88.0 (Apr. 24 1977)
69121	50.8	223.8	231.6	125.2	115.2	276.1	167.7	100.1	7.7	1.8	24.2	39.4	1,365.4	198.0 (Nov. 7 1981)

Table I-3 AVERAGE MONTHLY RAINFALL AND MAXIMUM DAILY RAINFALL (3/3)

Code	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Maximum Daily Rainfall
04012	56.3	137.9	92.8	122.0	147.0	278.3	175.6	24.5	3.6	4.2	5.8	41.1	1,088.9	144.1 (Oct. 3, 1959)
04022	53.6	129.4	110.5	120.5	133.2	250.7	129.6	20.8	1.9	4.4	9.5	29.4	1,007.2	200.7 (May 5, 1954)
04032	66.4	119.0	94.9	113.2	129.7	250.8	130.9	24.0	2.0	4.4	16.9	33.3	1,003.3	137.8 (Oct. 18, 1952)
04042	68.2	115.9	119.8	104.7	139.0	243.0	133.6	29.0	5.4	7.6	23.1	32.2	1,017.9	242.5 (Apr. 8, 1946)
04052	53.6	123.8	105.2	97.0	138.2	255.0	132.2	31.8	4.8	9.9	18.0	25.9	1,003.2	240.0 (Apr. 8, 1946)
04062	68.8	122.0	102.5	126.1	149.3	261.6	144.5	30.3	6.8	9.2	17.1	34.0	1,073.3	195.9 (Apr. 27, 1979)
04080	68.0	141.5	95.3	138.3	167.0	281.5	135.1	30.8	9.4	11.6	18.6	42.3	1,131.7	142.2 (Sep. 18, 1972)
04100	49.2	94.3	85.0	119.8	132.9	279.6	140.9	32.6	6.7	9.2	8.9	36.5	996.5	142.5 (Oct. 6, 1966)
04110	45.6	131.4	94.7	122.4	139.0	288.8	139.7	31.2	10.4	8.0	9.9	32.0	1,050.5	147.2 (Oct. 6, 1966)
04120	59.0	115.8	82.8	126.8	143.4	298.6	148.4	33.0	12.7	7.1	13.5	38.7	1,076.7	174.6 (Sep. 18, 1972)
04130	59.6	99.9	87.3	137.6	136.0	279.9	139.3	32.8	8.6	14.2	13.1	27.2	1,041.9	167.8 (Oct. 6, 1966)
04140	48.2	109.5	95.2	136.7	136.6	284.1	132.0	33.9	6.5	5.1	10.1	23.9	1,021.5	155.6 (Oct. 6, 1966)
04150	56.6	97.1	69.5	134.1	131.2	257.1	125.6	26.6	5.5	8.6	7.6	27.9	941.1	134.5 (Aug. 29, 1976)
04160	67.0	143.4	105.0	146.2	181.8	309.2	158.2	31.3	7.1	8.1	18.8	42.9	1,207.4	216.4 (Aug. 23, 1971)
04170	59.2	127.8	93.3	129.8	147.8	305.3	147.5	32.2	6.5	9.9	12.9	20.4	1,083.6	303.3 (Sep. 28, 1959)
04180	41.8	96.6	81.0	128.1	141.1	261.8	119.9	26.5	3.9	17.8	4.8	13.5	928.0	150.8 (Jan. 11, 1974)
04200	48.7	80.6	72.0	110.0	100.3	226.2	89.0	23.1	1.5	5.4	5.7	7.8	773.3	124.4 (Sep. 18, 1972)
04250	44.8	134.4	103.7	126.8	148.9	238.7	134.2	41.7	3.7	8.7	11.0	25.8	1,022.4	145.3 (Oct. 13, 1970)
04260	39.7	119.5	92.2	125.2	138.2	239.4	140.0	38.9	5.6	5.0	10.9	20.5	975.0	141.3 (Oct. 6, 1966)
04270	38.1	116.3	83.9	138.5	149.4	233.3	128.1	35.6	7.6	5.7	9.4	17.2	963.1	98.6 (May 6, 1976)
04290	50.3	123.8	102.4	141.3	147.2	253.5	147.0	31.8	5.0	5.7	9.8	24.8	1,066.1	182.0 (Sep. 4, 1959)

Table I-4 CORRELATION COEFFICIENTS ON MONTHLY RAINFALL

Code \ Code	04032	04062	04180	04200	12022	12042	12081	26013	26042	26052	26062	26072	26281	63042	69012	69022	69032	69042	69052	69090	69110	69121
04032		0.908	-	-	0.607	0.664	0.731	0.783	0.779	0.784	0.701	0.755	0.575	0.600	0.855	0.847	0.835	0.810	0.657	0.760	0.804	0.556
04062	0.915		0.686	0.694	0.608	0.684	0.719	0.781	0.774	0.799	0.698	0.755	0.655	0.598	0.848	0.839	0.841	0.810	0.671	0.756	0.790	0.575
04180	-	0.727		0.800	-	-	-	-	-	-	-	-	0.609	-	0.690	0.682	0.558	0.662	0.581	-	-	-
04200	-	0.763	0.848		-	-	-	-	-	-	-	-	0.568	-	0.624	0.452	0.659	0.721	0.677	-	-	-
12022	0.639	0.639	-	-		-	0.559	0.594	0.598	0.536	0.575	0.576	0.328	0.480	0.608	0.607	0.542	0.694	0.570	0.648	-	-
12042	0.714	0.697	-	-	0.716		0.745	0.734	0.710	0.696	0.743	0.704	0.547	0.654	0.659	0.693	0.654	0.716	0.660	0.730	0.722	0.540
12081	0.791	0.777	-	-	0.684	0.806		0.712	0.697	0.595	0.720	0.724	0.776	0.574	0.647	0.738	0.650	0.656	0.657	0.853	0.865	0.663
26013	0.802	0.796	-	-	0.633	0.761	0.769		0.839	0.757	0.754	0.749	0.664	0.665	0.762	0.793	0.742	0.765	0.682	0.650	0.746	0.543
26042	0.799	0.797	-	-	0.635	0.741	0.785	0.851		0.810	0.718	0.761	0.614	0.626	0.783	0.840	0.769	0.821	0.663	0.662	0.755	0.487
26052	0.804	0.820	-	-	0.580	0.732	0.743	0.781	0.827		0.673	0.743	0.564	0.568	0.806	0.805	0.796	0.774	0.593	0.594	0.633	0.626
26062	0.723	0.724	-	-	0.621	0.776	0.794	0.781	0.748	0.718		0.277	0.622	0.369	0.680	0.759	0.701	0.728	0.616	0.721	0.765	0.523
26072	0.781	0.781	-	-	0.621	0.741	0.791	0.779	0.788	0.777	0.371		0.664	0.542	0.744	0.786	0.736	0.762	0.690	0.741	0.705	0.671
26281	0.685	0.727	0.724	0.713	0.561	0.682	0.837	0.749	0.731	0.701	0.749	0.757		0.518	0.633	0.707	0.609	0.637	0.499	-	-	-
63042	0.645	0.651	-	-	0.538	0.627	0.667	0.706	0.670	0.623	0.452	0.602	0.673		0.596	0.618	0.593	0.593	0.482	0.224	0.784	0.480
69012	0.867	0.862	0.731	0.708	0.644	0.699	0.746	0.735	0.805	0.826	0.712	0.755	0.706	0.650		0.845	0.823	0.825	0.634	0.644	0.769	0.468
69022	0.864	0.857	0.730	0.599	0.647	0.728	0.793	0.819	0.856	0.833	0.788	0.816	0.781	0.677	0.861		0.863	0.847	0.644	0.760	0.875	0.643
69032	0.853	0.858	0.658	0.759	0.587	0.698	0.763	0.767	0.796	0.817	0.736	0.770	0.740	0.652	0.836	0.881		0.835	0.615	0.716	0.805	0.608
69042	0.828	0.830	0.726	0.790	0.724	0.749	0.753	0.798	0.800	0.804	0.751	0.794	0.716	0.646	0.842	0.865	0.854		0.652	0.736	0.861	0.595
69052	0.650	0.640	0.649	0.747	0.612	0.694	0.745	0.668	0.657	0.610	0.645	0.700	0.603	0.533	0.645	0.653	0.627	0.666		0.647	0.124	0.463
69090	0.810	0.788	-	-	0.705	0.784	0.872	0.700	0.751	0.726	0.767	0.781	-	0.482	0.718	0.791	0.783	0.792	0.752		0.815	0.572
69110	0.861	0.857	-	-	0.630	0.788	0.900	0.806	0.818	0.771	0.842	0.796	-	0.854	0.855	0.913	0.877	0.762	0.324	-		0.831
69121	0.659	0.667	-	-	0.518	0.652	0.725	0.648	0.619	0.734	0.666	0.755	-	0.626	0.624	0.731	0.723	0.695	0.466	-	0.867	

Note: ① above the diagonal / ② below the diagonal

1 Excluding no rainfall month

2 Using all data

Table I-5 DAILY RAINFALL PROBABILITY BY IWAI METHOD

Unit : mm/day

Code	Return Period 1/5	1/10	1/20	1/50	1/100	1/200	1/500	1/1000	No. of Sample
04022	111.7	133.5	154.0	180.0	199.3	218.5	243.8	263.1	1921-1981 N=42
04032	97.8	111.2	123.2	137.7	148.1	158.1	170.8	180.2	1921-1982 N=43
04042	111.8	130.6	148.0	169.7	185.6	201.2	221.6	237.0	1921-1981 N=50
04052	113.4	135.2	156.9	186.3	209.3	233.0	265.8	291.7	1921-1981 N=45
04062	121.7	142.8	162.3	186.6	204.4	221.9	244.7	261.9	1921-1982 N=49
04160	116.7	137.3	157.6	184.5	205.2	226.5	255.4	278.0	1933-1981 N=49
12022	99.5	114.9	128.8	145.8	158.1	169.9	185.2	196.5	1921-1982 N=40
12042	121.2	148.2	174.2	208.2	234.2	260.4	295.7	323.0	1921-1982 N=38
26013	103.4	120.9	138.0	160.9	178.6	196.8	221.6	241.1	1921-1982 N=57
26042	112.1	132.2	151.1	175.1	193.0	210.8	234.2	252.0	1921-1982 N=48
26052	118.6	140.2	161.6	190.1	212.3	235.1	266.3	290.8	1921-1982 N=45
26062	116.9	136.8	154.9	177.2	193.4	209.1	229.4	244.6	1920-1982 N=41
26072	110.4	132.2	153.9	183.0	205.7	229.2	261.4	286.9	1931-1982 N=45
63042	85.1	101.1	116.5	136.5	151.6	166.9	187.3	203.1	1923-1982 N=38
69012	118.9	136.4	152.6	172.7	187.3	201.7	220.4	234.5	1920-1982 N=54
69022	111.0	125.1	137.4	152.0	162.2	171.8	183.9	192.7	1921-1982 N=51
69032	126.3	144.0	159.7	178.4	191.6	204.3	220.3	232.0	1921-1982 N=44
69042	117.0	142.1	167.0	200.5	226.7	253.7	290.8	320.1	1921-1982 N=48
69052	141.7	166.4	189.0	217.3	238.0	258.3	284.7	304.6	1922-1982 N=33

Table I-6 MONTHLY RUNOFF RECORD AT CT-5A, D.A. 936 km^2

(Unit : cum/s)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1969	14.89	20.86	45.02	60.82	246.08	760.50	591.00	670.28	117.26	46.59	19.89	14.86	2,608.05
1970	17.34	158.05	285.05	124.53	499.04	574.74	1456.00	666.84	608.41	137.32	61.96	40.48	4,629.76
1971	34.08	98.05	148.21	207.80	352.89	746.68	1181.60	547.60	126.33	70.24	35.09	26.02	3,574.59
1972	13.24	9.20	8.68	45.90	63.14	781.05	1683.00	942.69	509.24	165.29	74.70	63.84	4,359.97
1973	34.80	39.64	364.32	218.88	203.14	867.94	1390.00	461.88	214.60	120.38	69.56	61.98	4,101.12
1974	122.42	143.90	101.07	96.32	345.96	186.33	2406.00	1081.00	216.98	190.10	90.22	58.08	6,714.35
1975	44.04	169.93	253.98	150.93	163.88	861.00	1440.00	645.00	222.88	121.40	61.87	46.72	4,181.63
1976	32.70	177.42	51.17	56.75	249.63	955.00	1038.00	1167.89	120.06	60.56	24.29	15.09	3,948.56
1977	25.58	48.77	21.42	37.76	63.17	302.74	286.88	102.06	37.98	21.34	15.40	15.80	978.90
1978	15.45	94.83	68.46	389.37	288.42	973.82	1729.82	255.98	98.09	48.01	20.59	13.84	3,966.68
1979	16.05	54.93	311.04	77.99	85.51	1119.71	601.80	92.87	42.70	25.05	13.60	8.00	2,449.25
1980	14.20	831.37	-	251.90	290.65	945.00	2386.59	329.80	101.45	59.70	43.75	36.75	-
1981	53.15	170.95	218.10	203.10	301.40	639.40	1044.25	-	266.95	69.85	32.10	23.60	-
1982	25.28	104.10	178.69	148.64	199.05	292.00	669.90	158.94	85.75	59.05	40.79	38.67	2,000.86
1983	6.05	40.22	133.18	104.11	362.56	1221.13	4577.94	2548.79	278.60	147.60	99.40	57.20	9,576.77
MEAN	31.28	144.15	156.31	144.99	247.63	735.14	1454.19	690.83	203.15	89.50	46.88	34.93	3,978.78

Note: - ; Missing Data

Table I-7 RESULTS OF WATER QUALITY ANALYSIS (1/2)

SSP = Soluble Sodium Percentage
SAR = Sodium Adsorption Ratio
RSC = Residual Sodium Carbonate

Sample No.	Location	Date	PH	No2 PPM	ECx10[6] at 25°	Irrigation Class	Milliequivalent Per Litre (Lower Figure in ppm) Ca	Mg	Na	K	Co_3	HCO_3	Cl	So_4	No_3	SSP	SAR	RSC meg./l	Fe (Iron) Total	Fe (Iron) Dissolved
1	Upper Mae Wong Damsite	Dec. 1984	7.9	0	79	Cl - Sl	0.41 8	0.09 1	0.25 6	0.01 <1	0	0.75 46	0.07 2	0.02 1	<0.01 0.24	33	0.5	0.25	<0.01 0.05	0 0
2	" "	Sep. 1985	6.9	<0.01	52	Cl - Sl	0.25 5	0.09 1	0.10 2	0.07 3	0	0.40 24	0.10 3	0.02 1	<0.01 0.24	20	0.2	0.06	0 0	0 0
3	" "	Sep. 1985	7.0	0.01	55	Cl - Sl	0.24 5	0.16 2	0.10 2	0.09 3	0	0.48 29	0.10 3	0.02 1	0 0	17	0.2	0.08	0 0	0 0
4	Khao Chon Kan	Dec. 1984	7.7	0	100	Cl - Sl	0.43 9	0.21 2	0.29 7	0.01 <1	0	0.91 55	0.05 2	0.03 1	0.01 0.38	31	0.5	0.27	0.02 0.30	<0.01 0.05
5	" "	Sep. 1985	6.9	<0.01	80	Cl - Sl	0.34 7	0.15 2	0.20 5	0.12 5	0	0.74 45	0.10 3	0.02 1	<0.01 0.03	25	0.4	0.25	0.01 0.20	<0.01 0.10
6	Wang Sawatdi	Dec. 1984	7.1	0.01	170	Cl - Sl	0.62 12	0.39 5	0.68 16	0.08 3	0	1.70 104	0.12 4	0.03 1	<0.01 0.17	40	1.0	0.69	0.03 0.50	<0.01 0.05
7	Sawang Arom	Dec. 1984	7.5	0.01	160	Cl - Sl	0.60 12	0.32 4	0.70 16	0.15 6	0	1.38 84	0.23 8	0.06 3	<0.01 0.18	43	1.0	0.46	0.03 0.50	<0.01 0.10
8	Wong Ma	Aug. 1985	6.8	0.02	170	Cl - Sl	0.82 16	0.41 5	0.70 16	0.12 5	0	1.77 108	0.15 5	0.06 3	0.01 0.44	34	0.9	0.57	0.03 0.50	<0.01 0.10
9	Khlong Saingu	Aug. 1985	7.4	0.02	120	Cl - Sl	0.67 13	0.22 3	0.40 9	0.14 5	0	1.26 77	0.10 3	0.05 2	<0.01 0.34	28	0.6	0.37	<0.01 0.10	0 0
10	Ban Tha Ta Yu	Aug. 1985	7.2	0.02	120	Cl - Sl	0.63 13	0.23 3	0.30 7	0.16 6	0	1.20 73	0.13 5	0.03 1	0.01 0.43	23	0.5	0.34	0.01 0.20	<0.01 0.10
11	Khlong Nam Hom	Aug. 1985	6.9	0.03	250	Cl - Sl	1.09 22	0.52 6	0.90 21	0.27 10	0	2.51 153	0.26 9	0.12 6	0.02 1.34	32	1.0	0.90	0.04 0.80	0.02 0.40
12	Khum Lard Boriban	Sep. 1985	7.4	0.01	150	Cl - Sl	0.69 13	0.36 4	0.40 9	0.08 3	0	1.52 93	0.10 3	0.04 2	0.01 0.43	26	0.6	0.49	0.04 0.80	0.01 0.20

Table I-7 RESULTS OF WATER QUALITY ANALYSIS (2/2)

Sample No.	Location	Date	PH	No2 PPM	ECx10⁶ at 25°	Irrigation Class	Milliequivalent Per Litre (Lower Figure in ppm) Ca	Mg	Na	K	Co_3	HCO_3	Cl	So_4	No_3	SSP	SAR	RSC meg./1	Fe (Iron) Total	Dissolved
13	Ban Wang Thap Kwian	Aug. 1985	7.2	-	230	C1 - S1	0.77 15	0.44 5	1.00 23	0.22 9	0	1.98 121	0.28 10	0.04 2	<0.01 0.36	41	1.3	0.77	0.03 0.6	0 0
14	Ban San Chabkai To	Aug. 1985	7.5	-	270	C2 - S1	0.22 4	1.22 15	1.20 28	0.26 10	0	2.36 144	0.38 13	0.04 2	<0.01 0.24	41	1.4	0.92	0.16 3.00	0 0
15	" "	Aug. 1985	7.2	-	210	C1 - S1	0.99 20	0.28 3	0.60 14	0.19 7	0	1.94 118	0.20 7	0.02 1	0.01 0.46	29	0.7	0.67	0.02 0.40	0 0
16	Lat Yao	Aug. 1985	8.2	-	360	C2 - S1	0.77 15	0.83 11	2.00 46	0.20 8	0.16 5	3.45 210	0.23 8	0.03 1	0.01 0.52	32	2.2	1.95	0 0	0 0
17	Ban Nong Khon	Aug. 1985	7.2	-	150	C1 - S1	0.83 17	0.27 3	0.30 7	0.39 7	0	1.43 87	0.10 3	0.02 1	0.01 0.54	19	0.4	0.33	0.02 0.40	0 0
18	Ban Wang Nam Khao	Aug. 1985	7.1	-	220	C1 - S1	0.88 18	0.56 7	0.50 11	0.19 15	0	2.08 127	0.18 6	0.02 1	0.04 2.28	21	0.6	0.64	0.02 0.40	0 0
19	" "	Aug. 1985	7.3	-	160	C1 - S1	0.77 15	0.45 5	0.30 7	0.29 11	0	1.42 87	0.10 3	0.08 4	0.02 1.40	17	0.4	0.21	0.02 0.40	0.01 0.20
20	Ban Pro	Aug. 1985	6.8	-	150	C1 - S1	0.72 14	0.22 5	0.40 9	0.31 12	0	1.22 74	0.18 6	0.28 13	0.01 0.58	24	0.6	0.28	0.03 0.60	0.02 0.40
21	Ban Pang Ma Kha	Aug. 1985	7.2	-	170	C1 - S1	0.88 18	0.45 5	0.30 7	0.20 8	0	1.51 92	0.10 3	0.03 1	0.01 0.58	16	0.4	0.18	0.01 0.20	0 0

SSP = Soluble Sodium Percentage
SAR = Sodium Adsorption Ratio
RSC = Residual Sodium Carbonate

Table I-8 RESULTS OF TANK MODEL ANALYSIS

Stream gage station CT-5A, D.A. 936 km

Water	Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
R	(mm)	1,707.5	1,093.1	1,172.9	1,455.3	1,811.6	1,379.0	1,332.9	975.8	1,329.9	1,111.0
Qo	(m^3/s)	4,629.76	3,574.59	4,359.97	4,101.12	6,714.35	4,181.63	3,948.56	978.9	3,966.68	2,449.25
Fo		0.250	0.302	0.343	0.260	0.342	0.280	0.273	0.093	0.275	0.203
Qc	(m^3/s)	6,226.27	2,580.06	2,449.58	4,242.82	5,069.67	3,651.33	4,174.38	1,736.21	4,278.16	3,147.04
Fc		0.337	0.218	0.193	0.269	0.258	0.244	0.289	0.164	0.297	0.261
Qc/Qo		1.34	0.72	0.56	1.03	0.76	0.87	1.06	1.77	1.08	1.28

Water	Year	/1 1980	/2 1981	1982	Mean
R	(mm)	/1 1,248.5	/2 1,019.6	1,138.4	1,290.4
Qo	(m^3/s)	5,291.16	3,023.0	2,000.86	3,786.13
Fo		0.391	0.274	0.162	0.271
Qc	(m^3/s)	5,087.59	2,176.51	2,998.52	3,678.32
Fc		0.376	0.197	0.243	0.263
Qc/Qo		0.96	0.72	1.50	0.97

Where ; R - Annual Rainfall
Qo- Observed Annual Runoff
Fo- Runoff Rate of Qo
Qc- Calculated Annual Runoff
Fc- Runoff Rate of Qc

Note ; /1 - Excluding Nov.
/2 - Excluding Jan.

Table I-9 CALCULATED MONTHLY RAINFALL FOR RUNOFF ANALYSIS AT CT. 5A

Water Year	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1954	22.0	159.9	152.1	145.7	208.3	302.2	128.6	2.1	0	1.8	0	89.2	1,211.9
1955	151.4	156.3	171.2	202.3	191.4	260.7	41.0	101.1	0	0	81.3	58.9	1,415.6
1956	144.2	199.7	96.5	192.6	221.2	247.9	160.4	25.0	0	24.8	0	78.5	1,390.8
1957	110.7	65.5	205.1	217.3	213.8	349.3	166.0	35.6	0	32.0	0	93.3	1,488.6
1958	24.9	100.2	219.4	180.2	181.6	333.8	136.1	0	0	0	1.1	90.9	1,268.2
1959	77.8	138.5	140.0	258.4	170.8	340.8	135.5	32.7	0	0.4	0	0	1,294.9
1960	33.3	148.5	159.2	152.4	194.7	189.3	239.1	62.0	0.4	0	31.6	38.0	1,248.5
1961	94.2	225.0	150.9	189.8	267.0	223.8	209.1	2.5	34.2	5.2	0	31.9	1,433.6
1962	136.4	116.1	160.9	206.8	183.5	338.4	136.3	26.6	2.9	0	28.4	32.4	1,368.7
1963	81.1	106.2	145.2	164.9	216.1	257.5	268.2	92.2	0	0	2.0	38.8	1,372.2
1964	97.4	219.8	160.9	186.8	238.3	342.3	246.5	60.9	1.7	0	78.0	7.1	1,639.7
1965	40.1	162.7	156.8	131.5	237.3	252.0	159.9	61.8	0	113.1	34.4	35.1	1,384.7
1966	64.0	164.7	137.0	163.2	195.2	153.9	264.5	55.0	63.3	0	0	0	1,260.8
1967	125.1	185.2	131.7	97.1	156.5	192.6	133.1	56.1	0	0	29.7	31.6	1,138.7
1968	152.9	170.4	129.2	236.7	156.1	135.8	110.4	23.9	0	61.4	0	30.8	1,207.6
1969	35.4	141.1	178.0	160.8	189.0	244.3	122.9	57.6	0	0	22.3	61.3	1,212.7
1970	54.4	232.9	177.3	252.9	335.2	316.6	235.1	40.3	25.0	0.4	5.3	32.1	1,707.5
1971	74.5	196.0	127.4	109.9	216.0	222.8	130.2	5.6	0	0	9.2	1.5	1,093.1
1972	22.1	136.7	145.8	100.6	151.0	237.8	199.3	62.2	44.3	0	0	73.0	1,172.8
1973	39.4	285.4	252.6	214.7	138.3	274.4	94.4	14.5	0	3.0	1.4	137.2	1,455.3
1974	133.1	179.4	106.1	180.5	154.1	400.6	302.2	65.6	15.6	128.3	62.0	84.1	1,811.6
1975	66.1	194.5	128.2	167.0	201.1	224.8	198.6	100.4	18.2	0	25.7	54.4	1,379.0
1976	36.8	285.5	106.8	107.6	248.4	286.8	168.8	44.9	5.5	16.0	0	25.8	1,332.9
1977	111.8	153.4	62.8	128.7	133.5	225.0	83.6	8.8	14.5	0.3	44.2	0	966.6
1978	54.6	218.1	132.4	232.3	234.7	322.4	118.8	0.7	0	5.6	10.0	0.3	1,329.9
1979	40.2	174.0	212.3	95.4	124.5	417.7	22.6	0	0	0	1.7	22.6	1,111.0
1980	86.1	114.1	207.7	216.1	177.6	446.1	187.0	7.4	0.6	0	0	13.5	1,456.2
1981	75.0	102.0	143.7	152.8	261.8	155.9	128.4	197.5	0	0	0	0	1,217.1
1982	9.3	179.5	100.7	182.1	176.3	324.5	117.8	17.3	0	9.6	0	22.3	1,139.4
1983	24.6	125.3	139.7	178.5	175.4	318.9	537.3	114.6	8.8	2.2	26.2	12.2	1,663.7
Mean	74.0	167.9	151.3	173.5	198.3	277.1	172.7	45.8	7.8	13.5	16.5	39.9	1,339.1

Table I-10 MONTHLY RIVER RUNOFF SIMULATED BY TANK MODEL
(1,000 cum/sq. km)
THE MAE WONG RIVER AT GAGING STATION : CT-5A

Water Year	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1954	0.9	1.6	8.9	18.2	40.3	83.1	128.8	9.0	3.8	2.9	1.7	1.0	300
1955	0.9	6.2	21.0	27.1	51.7	96.0	67.0	11.6	4.6	3.6	3.0	2.5	295
1956	1.9	5.5	17.9	13.2	62.8	108.1	82.6	15.5	5.6	4.7	3.7	3.0	324
1957	2.6	1.9	12.5	48.5	74.8	106.0	172.2	14.0	5.8	4.9	4.0	3.3	451
1958	2.3	1.6	14.5	39.1	39.5	104.9	135.3	11.7	5.1	4.1	3.0	2.1	363
1959	1.6	1.5	7.8	20.3	77.9	107.4	132.8	16.1	5.1	4.1	3.0	1.7	380
1960	0.4	0.5	8.7	15.8	36.6	62.2	109.7	27.5	4.1	3.2	2.2	1.3	272
1961	0.5	5.8	27.6	20.3	79.9	103.9	111.3	20.2	4.7	4.0	2.9	1.7	383
1962	1.2	1.4	5.5	21.9	57.3	116.0	128.7	12.3	4.8	3.8	2.8	1.8	358
1963	0.9	0.8	2.7	12.8	43.4	87.5	158.0	54.7	4.9	4.0	2.9	1.7	374
1964	0.9	3.9	32.9	41.5	54.9	122.2	175.9	55.8	6.0	5.0	4.1	3.4	506
1965	2.2	2.2	16.9	14.7	37.6	97.4	102.2	24.6	5.7	5.6	4.7	3.9	318
1966	3.1	3.4	12.4	14.5	46.4	85.6	70.7	39.5	6.6	6.1	5.0	3.6	297
1967	2.9	4.2	17.7	11.6	12.0	48.1	66.8	15.1	5.8	4.8	3.8	2.8	196
1968	2.7	10.1	18.7	37.0	69.7	34.3	31.8	10.9	5.2	4.7	3.7	2.6	231
1969	1.4	1.9	4.2	5.6	22.7	70.2	54.6	61.9	10.8	4.3	1.8	1.4	241
1970	1.6	14.6	26.3	11.5	46.1	53.1	134.4	61.6	56.2	12.7	5.7	3.7	427
1971	3.1	9.1	13.7	19.2	32.6	68.9	109.1	50.5	11.7	6.5	3.2	2.4	330
1972	1.2	0.8	0.8	4.2	5.8	72.1	155.4	87.0	47.0	15.3	6.9	5.9	402
1973	3.2	8.6	33.6	20.2	18.8	80.1	128.3	42.6	19.8	11.1	6.4	5.7	379
1974	11.2	13.3	9.3	8.9	31.9	172.0	222.1	99.8	20.0	17.5	8.3	5.4	620
1975	4.1	15.8	23.4	14.0	15.2	79.8	133.0	59.4	20.5	11.2	5.7	3.9	386
1976	3.0	16.4	4.7	5.2	23.0	88.2	95.8	107.8	11.1	5.6	2.2	1.4	364
1977	2.4	4.5	2.0	3.5	5.8	27.9	26.5	9.4	3.5	2.0	1.4	1.5	90
1978	1.4	8.8	6.3	35.9	26.6	89.9	159.7	20.9	9.1	4.4	1.9	1.3	366
1979	1.5	5.1	28.7	7.2	7.9	103.4	55.6	8.6	3.9	2.3	1.3	0.7	226
1980	1.3	76.7	31.1	23.3	26.8	87.2	220.3	30.4	9.4	5.5	4.0	3.4	520
1981	4.9	15.8	23.9	18.8	27.8	59.0	96.4	59.4	24.6	6.4	3.0	2.2	342
1982	2.3	9.6	16.5	13.7	18.4	27.0	61.8	14.7	7.9	5.5	3.8	3.6	185
1983	0.6	3.7	12.3	9.6	33.5	112.7	422.6	235.3	25.7	13.6	9.2	5.3	884
Mean	2.3	8.5	15.4	18.6	37.6	85.1	125.0	45.0	12.0	6.3	3.8	2.8	360

Note ; 1954 - 1968 ; generate by tank model
1969 - 1983 ; observed at CT-5A

Table I-11 ANNUAL MAXIMUM RIVER DISCHARGE (1/3)

1. Sakae Krang River Basin

Water Year	Date	Q (cms)	SQ (ℓ/s/km^2)
CT. 5A (DA = 936 km^2)			
1969	Nov.5	117.0	125
1970	Oct.1	283.0	302
1971	Oct.29	367.0	392
1972	Oct.6	230.0	246
1973	Sep.30	141.0	151
1974	Sep.26	493.0	527
1975	Oct.15	162.0	173
1976	Nov.2	329.0	351
1977	Oct.30	55.0	59
1978	Oct.1	592.0	632
1979	Aug.26	321.4	343
1980	May.22	403.7	431
1981	Nov.8	703.0	751 (max)
1982	Oct.15	86.1	92
1983	Oct.13	514.0	549
CT. 5 (DA = 930 km^2)			
1968	Mar.2	72	77
1969	Nov.5	400	430 (max)
1970	Oct.14	155	167
CT. 6 (DA = 588 km^2)			
1969	Nov.5	62.6	106
1970	Oct.31	213	362
1971	Oct.27	107	182
1972	Oct.6	196	333
1973	Sep.22	52.5	89
1974	Oct.12	363	617 (max)
1975	Oct.16	219	372
CT. 7 (DA = 403 km^2)			
1975	Nov.11	67	166
1976	Sep.8	45	112
1977	-	-	-
1978	Oct.3	171.4	425
1979	Sep.26	203.0	504
1980	Oct.1	184.0	457
1981	Nov.8	304.9	757 (max)
1982	Oct.21	25.4	63
CT. 4 (DA = 1,382 km^2)			
1975	Oct.19	81	59
1976	Nov.4	110	80
1977	Sep.23	35	25
1978	Oct.2	121	88
1979	Sep.28	107	77
1980	Oct.3	92.2	67
1981	Nov.9	260.6	189 (max)
1982	Oct.18	46.8	34

Table I-11 ANNUAL MAXIMUM RIVER DISCHARGE (2/3)

CT. 3 (DA = 670 km^2)

1967	Oct.3	31.3	47
1968	May.6	23.2	35
1969	Nov.5	63.0	94
1970	Oct.1	155.0	231 (max)
1971	Oct.28	68.0	101
1972	Oct.6	135.0	201

CT. 9 (DA = 541 km^2)

1977	Oct.8	7.3	13
1978	Oct.2	58.3	108
1979	Sep.26	42.8	79
1980	Oct.1	129.8	240
1981	Nov.1	174.6	323 (max)
1982	Oct.20	55.6	103

CT. 8 (DA = 3,256 km^2)

1975	Oct.11	161.9	50
1976	Nov.8	121	37
1977	Sep.26	6.6	2
1978	Oct.6	196.6	60 (max)

2. Other River Basin

Station	DA (km^2)	Water Year	Date	Max Q (cms)	Specific Q ($1/s/km^2$)
YOM River Basin					
Y.1'	7,590	1939	Aug.26	2,940	387
Y.2	5,512	1952	Sep.20	3,300	599
Y.3A	13,583	1974	Aug.19	1,643	121
Y.4	17,731	1980	Sep.10	576	32
Y.6	12,658	1961	Sep.12	3,112	246
Y.11	5,542	1957	Sep.1	2,708	489
Y.13	382	1961	Aug.22	832	2178
Y.14	12,131	1973	Sep.1	4,060	335
Y.20	5,410	1973	Aug.28	3,000	555
Y.26	785	1980	Sep.7	386	492
NAM River Basin					
N.1	4,609	1963	Sep.12	2,800	608
N.2	16,862	1952	Sep.22	4,050	240
N.4	19,384	1961	Sep.12	2,166	112
N.6A	13,173	1963	Sep.14	5,260	399
N.13	8,993	1963	Sep.13	4,350	484
N.17	1,156	1973	Aug.27	1,843	1,594
N.22	4,761	1980	Sep.11	867	182
N.23	16,336	1970	Aug.25	3,636	223
N.24	1,861	1980	Sep.7	680	365

Table I-11 ANNUAL MAXIMUM RIVER DISCHARGE (3/3)

Station	DA	Water Year	Date	Max Q	Specific Q
	(km^2)			(cms)	($1/s/km^2$)
N.26	17,350	1970	Aug.26	2,645	152
N.27	19,549	1966	Aug.27	1,592	81
N.28	476	1971	Jul.14	580	1,218
N.28A	368	1978	Aug.13	720	1,957
N.33	2,463	1978	Aug.13	2,196	892
N.42	2,107	1980	Jul.24	1,020	484
MEA KLONG River Basin					
K.4	26,441	1953	Aug.24	6,000	227
K.6	11,010	1962	Sep.20	2,746	249
K.8	26,421	1961	Aug.28	4,363	165
K.9	6,902	1974	Aug.21	3,958	573
K.10	7,008	1974	Aug.21	3,294	470
K.11	26,449	1974	Aug.21	3,592	136
K.13	4,042	1966	Sep,10	3,146	778
K.17	1,355	1968	Oct,22	954	704
K.19	8,437	1972	Sep.20	2,770	328
K.20	11,184	1972	Sep.20	2,251	201
K.22A	321	1982	Jul.3	438	1,364
K.27	1,921	1974	Oct.13	438	228
K.28	183	1981	Nov.7	323	1,765
PING River Basin					
P.1	6,355	1973	Aug.25	729	115
P.4A	1,902	1973	Aug,24	739	389
P.5	1,569	1973	Aug.26	376	240
P.13	1,765	1973	Aug.24	1,251	709
P.14	3,853	1960	Aug.21	1,030	267
P.14A	3,909	1962	Oct.2	647	166
P.19A	14,023	1973	Sep.21	1,888	135
P.21	515	1975	Sep.22	96	186
P.22	135	1963	Oct.27	63	467
P.23	1,777	1960	Dec.3	420	236
P.24	616	1964	Oct.4	421	683
P.28	1,261	1973	Aug.24	503	399
P.29	1,970	1973	Sep.20	470	239
PASAK River Basin					
S.2	14,522	1964	-	1,519	105
S.6	1,006	1956	Aug.14	825	820
S.7	177	1972	Sep.18	167	2,034
S.9	14,374	1978	Oct.3	3,254	226
S.10	268	1980	Sep.7	444	1,657
S.12	471	1978	Sep.22	173	367
S.13	359	1978	Sep.30	287	799
CHAO PARAYA River Basin					
C.1	118,816	1942	Sep.24	6,500	55
C.2	110,569	1961	Oct.13	4,721	43

Table I-12 FLOOD PROBABILITY AT CT-7

(Unit : cms)

Dam	1/10	1/20	1/100	1/200	1/500	1/1,000
Specific Discharge (cms/km^2)	0.78	1.02	1.65	1.97	2.43	2.82
Upper Mae Wong	480	630	1,010	1,210	1,490	1,730

Specific discharge at CT.7 is applied

			Return Period					
Station	N	1/5	1/10	1/20	1/100	1/200	1/500	1/1,000
CT.4	8	110	147	186	292	345	422	468
CT.5A	14	484	640	801	1,210	1,405	1,679	1,902
CT.6	7	440	596	764	1,213	1,436	1,760	2,030
CT.7	7	560	778	1,015	1,651	1,968	2,429	2,815
CT.9	6	234	330	434	716	857	1,063	1,236

N : Number of samples
Unit : l/s/km^2

Table I-13 PROBABLE FLOOD BY RATIONAL FORMULA

Upper Mae Wong Dam Drainage Area 612 Km^2

		$^1/_{10}$	$^1/_{20}$	$^1/_{50}$	$^1/_{100}$	$^1/_{200}$	$^1/_{500}$	$^1/_{1,000}$
Max. R24	mm/day	166	189	217	238	260	296	323
n		0.49	0.43	0.38	0.36	0.34	0.30	0.28
Tp	hr	28.7	27.0	25.6	24.6	23.7	22.6	21.8
Re	mm/hr	6.3	7.5	8.8	9.8	10.9	12.6	13.8
Q	Cms/Km^2	1.40	1.67	1.96	2.18	2.42	2.80	3.07

FLOOD ANALYSIS BY NAKAYASU METHOD

D	.HR	RAINFALL	EFF.RAIN.	UNIT-HYD.	DISCHARGE
7	4	9.2	6.4	0.629E-02	10.040
7	5	4.8	3.4	0.332E-01	10.235
7	6	11.2	7.8	0.878E-01	10.726
7	7	10.4	7.3	0.175E+00	11.729
7	8	0.0	0.0	0.299E+00	13.446
7	9	0.0	0.0	0.464E+00	16.004
7	10	1.2	0.8	0.671E+00	19.507
7	11	3.0	2.1	0.925E+00	24.064
7	12	0.0	0.0	0.123E+01	29.787
7	13	0.0	0.0	0.158E+01	36.761
7	14	0.0	0.0	0.199E+01	45.063
7	15	2.7	1.9	0.245E+01	54.773
7	16	13.6	9.5	0.296E+01	66.042
7	17	16.1	11.3	0.354E+01	79.150
7	18	1.8	1.3	0.418E+01	94.400
7	19	29.0	20.3	0.488E+01	112.125
7	20	5.2	3.6	0.564E+01	132.799
7	21	3.8	2.7	0.647E+01	156.775
7	22	1.8	1.3	0.737E+01	184.349
7	23	6.2	4.3	0.834E+01	215.801
7	24	10.8	7.6	0.937E+01	251.453
8	1	6.8	4.8	0.105E+02	291.665
8	2	4.5	3.1	0.117E+02	336.777
8	3	9.5	6.6	0.108E+02	373.406
8	4	9.4	6.6	0.997E+01	408.436
8	5	2.4	1.7	0.922E+01	432.621
8	6	1.3	0.9	0.853E+01	447.337
8	7	0.0	0.0	0.789E+01	468.198
8	8	0.0	0.0	0.729E+01	495.305
8	9	0.0	0.0	0.675E+01	526.960
8	10	0.0	0.0	0.624E+01	560.558
8	11	0.0	0.0	0.577E+01	600.632
8	12	0.0	0.0	0.534E+01	647.242
8	13	0.0	0.0	0.493E+01	700.452
8	14	0.0	0.0	0.456E+01	756.297
8	15	0.0	0.0	0.422E+01	798.563
8	16	0.0	0.0	0.390E+01	823.484
8	17	0.0	0.0	0.361E+01	852.278
8	18	0.0	0.0	0.339E+01	844.629
8	19	0.0	0.0	0.322E+01	835.785
8	20	0.0	0.0	0.305E+01	827.703
8	21	0.0	0.0	0.290E+01	823.211
8	22	0.0	0.0	0.275E+01	815.074
8	23	0.0	0.0	0.251E+01	795.959
8	24	0.0	0.0	0.248E+01	771.635
9	1	0.0	0.0	0.235E+01	745.373
9	2	0.0	0.0	0.223E+01	709.381
9	3	0.0	0.0	0.212E+01	663.452
9	4	0.0	0.0	0.201E+01	617.726
9	5	0.0	0.0	0.191E+01	573.665
9	6	0.0	0.0	0.181E+01	533.397
9	7	0.0	0.0	0.172E+01	496.955
9	8	0.0	0.0	0.163E+01	463.542
9	9	0.0	0.0	0.155E+01	433.588
9	10	0.0	0.0	0.147E+01	406.534
9	11	0.0	0.0	0.140E+01	381.530
9	12	0.0	0.0	0.133E+01	358.516
9	13	0.0	0.0	0.126E+01	336.877
9	14	0.0	0.0	0.120E+01	317.349
9	15	0.0	0.0	0.113E+01	299.531
9	16	0.0	0.0	0.108E+01	283.108
9	17	0.0	0.0	0.103E+01	268.143
9	18	0.0	0.0	0.990E+00	254.651
9	19	0.0	0.0	0.952E+00	242.255
9	20	0.0	0.0	0.915E+00	230.694
9	21	0.0	0.0	0.880E+00	219.789
9	22	0.0	0.0	0.846E+00	209.426
9	23	0.0	0.0	0.814E+00	199.584
9	24	0.0	0.0	0.783E+00	190.251
10	1	0.0	0.0	0.753E+00	181.393
10	2	0.0	0.0	0.724E+00	172.974
10	3	0.0	0.0	0.696E+00	164.971
10	4	0.0	0.0	0.669E+00	157.377
10	5	0.0	0.0	0.644E+00	150.234
10	6	0.0	0.0	0.619E+00	143.577
10	7	0.0	0.0	0.595E+00	137.320
10	8	0.0	0.0	0.573E+00	131.504
10	9	0.0	0.0	0.551E+00	126.113
10	10	0.0	0.0	0.529E+00	121.007
10	11	0.0	0.0	0.509E+00	116.155
10	12	0.0	0.0	0.490E+00	111.557
10	13	0.0	0.0	0.471E+00	107.240
10	14	0.0	0.0	0.453E+00	103.189
10	15	0.0	0.0	0.435E+00	99.363
10	16	0.0	0.0	0.419E+00	95.760
10	17	0.0	0.0	0.403E+00	92.391
10	18	0.0	0.0	0.387E+00	89.208
10	19	0.0	0.0	0.372E+00	86.165
10	20	0.0	0.0	0.358E+00	83.245
10	21	0.0	0.0	0.344E+00	80.437
10	22	0.0	0.0	0.331E+00	77.737
10	23	0.0	0.0	0.319E+00	75.140
10	24	0.0	0.0	0.306E+00	72.643
11	1	0.0	0.0	0.295E+00	70.242
11	2	0.0	0.0	0.283E+00	67.932
11	3	0.0	0.0	0.272E+00	65.711
11	4	0.0	0.0	0.262E+00	63.576
11	5	0.0	0.0	0.252E+00	61.522
11	6	0.0	0.0	0.242E+00	59.547
11	7	0.0	0.0	0.233E+00	57.647
11	8	0.0	0.0	0.224E+00	55.821
11	9	0.0	0.0	0.215E+00	54.064
11	10	0.0	0.0	0.207E+00	52.375
11	11	0.0	0.0	0.199E+00	50.750
11	12	0.0	0.0	0.192E+00	49.188
11	13	0.0	0.0	0.184E+00	47.686
11	14	0.0	0.0	0.177E+00	46.241
11	15	0.0	0.0	0.170E+00	44.852
11	16	0.0	0.0	0.164E+00	43.516
11	17	0.0	0.0	0.158E+00	42.231
11	18	0.0	0.0	0.152E+00	40.995
11	19	0.0	0.0	0.146E+00	39.807
11	20	0.0	0.0	0.140E+00	38.664
11	21	0.0	0.0	0.135E+00	37.565
11	22	0.0	0.0	0.130E+00	36.509
11	23	0.0	0.0	0.125E+00	35.492
11	24	0.0	0.0	0.120E+00	34.515
12	1	0.0	0.0	0.115E+00	33.575
12	2	0.0	0.0	0.111E+00	32.672
12	3	0.0	0.0	0.107E+00	31.802
12	4	0.0	0.0	0.103E+00	30.967
12	5	0.0	0.0	0.986E-01	30.163
12	6	0.0	0.0	0.0	28.779
12	7	0.0	0.0	0.0	27.741
12	8	0.0	0.0	0.0	26.317
12	9	0.0	0.0	0.0	25.002
12	10	0.0	0.0	0.0	24.426
12	11	0.0	0.0	0.0	23.873
12	12	0.0	0.0	0.0	23.262
12	13	0.0	0.0	0.0	22.554
12	14	0.0	0.0	0.0	22.073
12	15	0.0	0.0	0.0	21.610
12	16	0.0	0.0	0.0	21.165
12	17	0.0	0.0	0.0	20.558
12	18	0.0	0.0	0.0	19.251
12	19	0.0	0.0	0.0	17.827
12	20	0.0	0.0	0.0	17.408
12	21	0.0	0.0	0.0	15.199
12	22	0.0	0.0	0.0	14.655
12	23	0.0	0.0	0.0	14.224
12	24	0.0	0.0	0.0	13.943
13	1	0.0	0.0	0.0	13.380
13	2	0.0	0.0	0.0	12.534
13	3	0.0	0.0	0.0	11.985
13	4	0.0	0.0	0.0	11.610
13	5	0.0	0.0	0.0	10.918
13	6	0.0	0.0	0.0	10.259
13	7	0.0	0.0	0.0	10.090
13	8	0.0	0.0	0.0	10.000

Table I-14 UNIT HYDROGRAPH SIMULATION

FLOOD ANALYSIS BY NAKAYASU METHOD

D	.HR	RAINFALL	EFF.RAIN.	UNIT-HYD.	DISCHARGE
1	1	15.8	11.1	0.411E-02	0.045
1	2	8.2	5.7	0.217E-01	0.264
1	3	19.2	13.4	0.574E-01	0.815
1	4	17.8	12.5	0.115E+00	1.939
1	5	0.0	0.0	0.196E+00	3.864
1	6	0.0	0.0	0.303E+00	6.731
1	7	2.1	1.5	0.439E+00	10.656
1	8	5.1	3.6	0.605E+00	15.764
1	9	0.0	0.0	0.802E+00	22.177
1	10	0.0	0.0	0.103E+01	29.993
1	11	0.0	0.0	0.130E+01	39.297
1	12	4.6	3.2	0.160E+01	50.179
1	13	23.3	16.3	0.194E+01	62.807
1	14	27.7	19.4	0.232E+01	77.495
1	15	3.1	2.2	0.273E+01	94.583
1	16	49.8	34.9	0.319E+01	114.446
1	17	8.9	6.2	0.369E+01	137.616
1	18	6.5	4.5	0.423E+01	164.488
1	19	3.1	2.2	0.482E+01	195.395
1	20	10.6	7.4	0.545E+01	230.650
1	21	18.5	12.9	0.613E+01	270.614
1	22	11.7	8.2	0.695E+01	315.691
1	23	7.7	5.4	0.762E+01	366.262
1	24	16.3	11.4	0.705E+01	407.300
2	1	0.0	0.0	0.652E+01	446.528
2	2	0.0	0.0	0.603E+01	473.441
2	3	0.0	0.0	0.558E+01	489.519
2	4	0.0	0.0	0.516E+01	512.172
2	5	0.0	0.0	0.477E+01	541.469
2	6	0.0	0.0	0.441E+01	575.428
2	7	0.0	0.0	0.408E+01	611.177
2	8	0.0	0.0	0.377E+01	653.724
2	9	0.0	0.0	0.349E+01	703.114
2	10	0.0	0.0	0.323E+01	759.392
2	11	0.0	0.0	0.298E+01	818.118
2	12	0.0	0.0	0.276E+01	861.084
2	13	0.0	0.0	0.255E+01	883.936
2	14	0.0	0.0	0.236E+01	910.520
2	15	0.0	0.0	0.222E+01	895.562
2	16	0.0	0.0	0.210E+01	878.646
2	17	0.0	0.0	0.200E+01	861.949
2	18	0.0	0.0	0.190E+01	848.594
2	19	0.0	0.0	0.180E+01	830.503
2	20	0.0	0.0	0.171E+01	799.424
2	21	0.0	0.0	0.162E+01	761.753
2	22	0.0	0.0	0.154E+01	721.197
2	23	0.0	0.0	0.146E+01	668.981
2	24	0.0	0.0	0.139E+01	620.590
3	1	0.0	0.0	0.132E+01	575.740
3	2	0.0	0.0	0.125E+01	534.281
3	3	0.0	0.0	0.119E+01	496.477
3	4	0.0	0.0	0.113E+01	462.412
3	5	0.0	0.0	0.107E+01	431.234
3	6	0.0	0.0	0.101E+01	403.464
3	7	0.0	0.0	0.953E+00	378.508
3	8	0.0	0.0	0.914E+00	355.446
3	9	0.0	0.0	0.869E+00	334.017
3	10	0.0	0.0	0.823E+00	314.231
3	11	0.0	0.0	0.782E+00	296.267
3	12	0.0	0.0	0.742E+00	279.927
3	13	0.0	0.0	0.704E+00	264.875
3	14	0.0	0.0	0.673E+00	251.207
3	15	0.0	0.0	0.647E+00	238.567
3	16	0.0	0.0	0.622E+00	226.647
3	17	0.0	0.0	0.598E+00	215.436
3	18	0.0	0.0	0.575E+00	204.834
3	19	0.0	0.0	0.553E+00	194.758
3	20	0.0	0.0	0.532E+00	185.188
3	21	0.0	0.0	0.512E+00	176.113
3	22	0.0	0.0	0.492E+00	167.501
3	23	0.0	0.0	0.473E+00	159.314
3	24	0.0	0.0	0.455E+00	151.530
4	1	0.0	0.0	0.438E+00	144.144
4	2	0.0	0.0	0.421E+00	137.206
4	3	0.0	0.0	0.405E+00	130.758
4	4	0.0	0.0	0.389E+00	124.709
4	5	0.0	0.0	0.374E+00	119.105
4	6	0.0	0.0	0.360E+00	113.931
4	7	0.0	0.0	0.346E+00	109.032
4	8	0.0	0.0	0.333E+00	104.376
4	9	0.0	0.0	0.320E+00	99.964
4	10	0.0	0.0	0.308E+00	95.830
4	11	0.0	0.0	0.296E+00	91.959
4	12	0.0	0.0	0.285E+00	88.305
4	13	0.0	0.0	0.274E+00	84.869
4	14	0.0	0.0	0.263E+00	81.615
4	15	0.0	0.0	0.253E+00	78.487
4	16	0.0	0.0	0.244E+00	75.478
4	17	0.0	0.0	0.234E+00	72.584
4	18	0.0	0.0	0.225E+00	69.802
4	19	0.0	0.0	0.217E+00	67.126
4	20	0.0	0.0	0.208E+00	64.553
4	21	0.0	0.0	0.200E+00	62.078
4	22	0.0	0.0	0.193E+00	59.698
4	23	0.0	0.0	0.185E+00	57.410
4	24	0.0	0.0	0.178E+00	55.209
5	1	0.0	0.0	0.171E+00	53.092
5	2	0.0	0.0	0.165E+00	51.057
5	3	0.0	0.0	0.158E+00	49.100
5	4	0.0	0.0	0.152E+00	47.217
5	5	0.0	0.0	0.147E+00	45.407
5	6	0.0	0.0	0.141E+00	43.666
5	7	0.0	0.0	0.135E+00	41.992
5	8	0.0	0.0	0.130E+00	40.383
5	9	0.0	0.0	0.125E+00	38.835
5	10	0.0	0.0	0.120E+00	37.346
5	11	0.0	0.0	0.116E+00	35.914
5	12	0.0	0.0	0.111E+00	34.537
5	13	0.0	0.0	0.107E+00	33.213
5	14	0.0	0.0	0.103E+00	31.940
5	15	0.0	0.0	0.991E-01	30.716
5	16	0.0	0.0	0.953E-01	29.538
5	17	0.0	0.0	0.916E-01	28.406
5	18	0.0	0.0	0.881E-01	27.317
5	19	0.0	0.0	0.848E-01	26.269
5	20	0.0	0.0	0.815E-01	25.262
5	21	0.0	0.0	0.784E-01	24.294
5	22	0.0	0.0	0.754E-01	23.363
5	23	0.0	0.0	0.725E-01	22.467
5	24	0.0	0.0	0.697E-01	21.606
6	1	0.0	0.0	0.670E-01	20.777
6	2	0.0	0.0	0.645E-01	19.981
6	3	0.0	0.0	0.0	18.529
6	4	0.0	0.0	0.0	17.463
6	5	0.0	0.0	0.0	15.960
6	6	0.0	0.0	0.0	14.576
6	7	0.0	0.0	0.0	14.017
6	8	0.0	0.0	0.0	13.480
6	9	0.0	0.0	0.0	12.872
6	10	0.0	0.0	0.0	12.157
6	11	0.0	0.0	0.0	11.691
6	12	0.0	0.0	0.0	11.243
6	13	0.0	0.0	0.0	10.812
6	14	0.0	0.0	0.0	10.198
6	15	0.0	0.0	0.0	8.796
6	16	0.0	0.0	0.0	7.257
6	17	0.0	0.0	0.0	6.844
6	18	0.0	0.0	0.0	4.420
6	19	0.0	0.0	0.0	3.865
6	20	0.0	0.0	0.0	3.434
6	21	0.0	0.0	0.0	3.168
6	22	0.0	0.0	0.0	2.587
6	23	0.0	0.0	0.0	1.685
6	24	0.0	0.0	0.0	1.112
7	1	0.0	0.0	0.0	0.736
7	2	0.0	0.0	0.0	0.0

Table I-15 UNIT HYDROGRAPH CALCULATION -UPPER MAE WONG DAM- Case 1 (1/2)

FLOOD ANALYSIS BY NAKAYASU METHOD

D	.HR	RAINFALL	EFF.RAIN.	UNIT-HYD.	DISCHARGE
1	1	7.2	5.0	0.411E-02	0.021
1	2	7.3	5.1	0.217E-01	0.130
1	3	7.4	5.2	0.574E-01	0.422
1	4	7.7	5.4	0.115E+00	1.005
1	5	7.9	5.5	0.176E+00	2.009
1	6	8.0	5.6	0.303E+00	3.572
1	7	8.3	5.8	0.439E+00	5.850
1	8	8.5	5.9	0.605E+00	9.012
1	9	8.7	6.1	0.802E+00	13.236
1	10	9.2	6.4	0.103E+01	18.718
1	11	9.5	6.6	0.130E+01	25.663
1	12	9.8	6.9	0.160E+01	34.294
1	13	10.6	7.4	0.194E+01	44.846
1	14	11.2	7.8	0.232E+01	57.573
1	15	11.8	8.3	0.273E+01	72.746
1	16	13.3	9.7	0.319E+01	90.659
1	17	15.5	10.8	0.367E+01	111.634
1	18	18.5	12.9	0.423E+01	136.036
1	19	31.9	22.3	0.482E+01	164.307
1	20	12.6	8.8	0.545E+01	196.947
1	21	10.2	7.1	0.613E+01	234.391
1	22	8.9	6.2	0.685E+01	277.041
1	23	8.1	5.7	0.762E+01	325.279
1	24	7.5	5.2	0.705E+01	372.453
2	1	0.0	0.0	0.652E+01	418.770
2	2	0.0	0.0	0.603E+01	464.365
2	3	0.0	0.0	0.558E+01	509.130
2	4	0.0	0.0	0.516E+01	553.111
2	5	0.0	0.0	0.477E+01	596.227
2	6	0.0	0.0	0.441E+01	638.269
2	7	0.0	0.0	0.408E+01	679.095
2	8	0.0	0.0	0.377E+01	718.558
2	9	0.0	0.0	0.349E+01	756.117
2	10	0.0	0.0	0.323E+01	791.515
2	11	0.0	0.0	0.298E+01	824.398
2	12	0.0	0.0	0.276E+01	853.917
2	13	0.0	0.0	0.255E+01	879.396
2	14	0.0	0.0	0.236E+01	900.133
2	15	0.0	0.0	0.222E+01	914.208
2	16	0.0	0.0	0.210E+01	919.884
2	17	0.0	0.0	0.200E+01	913.995
2	18	0.0	0.0	0.190E+01	883.203
2	19	0.0	0.0	0.180E+01	845.962
2	20	0.0	0.0	0.171E+01	804.262
2	21	0.0	0.0	0.162E+01	759.016
2	22	0.0	0.0	0.154E+01	710.656
2	23	0.0	0.0	0.146E+01	659.413
2	24	0.0	0.0	0.139E+01	612.265
3	1	0.0	0.0	0.132E+01	563.906
3	2	0.0	0.0	0.125E+01	529.049
3	3	0.0	0.0	0.119E+01	492.444
3	4	0.0	0.0	0.113E+01	458.859
3	5	0.0	0.0	0.107E+01	428.077
3	6	0.0	0.0	0.101E+01	399.931
3	7	0.0	0.0	0.963E+00	374.276
3	8	0.0	0.0	0.914E+00	351.004
3	9	0.0	0.0	0.869E+00	330.281
3	10	0.0	0.0	0.823E+00	311.612
3	11	0.0	0.0	0.782E+00	294.469
3	12	0.0	0.0	0.742E+00	278.662
3	13	0.0	0.0	0.704E+00	264.052
3	14	0.0	0.0	0.673E+00	250.543
3	15	0.0	0.0	0.647E+00	237.883
3	16	0.0	0.0	0.622E+00	225.908
3	17	0.0	0.0	0.598E+00	214.583
3	18	0.0	0.0	0.575E+00	203.973
3	19	0.0	0.0	0.553E+00	193.747
3	20	0.0	0.0	0.532E+00	184.176
3	21	0.0	0.0	0.512E+00	175.130
3	22	0.0	0.0	0.492E+00	166.584
3	23	0.0	0.0	0.473E+00	158.512
3	24	0.0	0.0	0.455E+00	150.891
4	1	0.0	0.0	0.438E+00	143.698
4	2	0.0	0.0	0.421E+00	136.913
4	3	0.0	0.0	0.405E+00	130.519
4	4	0.0	0.0	0.389E+00	124.497
4	5	0.0	0.0	0.374E+00	118.834
4	6	0.0	0.0	0.360E+00	113.521
4	7	0.0	0.0	0.346E+00	108.552
4	8	0.0	0.0	0.333E+00	103.956
4	9	0.0	0.0	0.320E+00	99.691
4	10	0.0	0.0	0.308E+00	95.671
4	11	0.0	0.0	0.296E+00	91.873
4	12	0.0	0.0	0.285E+00	88.277
4	13	0.0	0.0	0.274E+00	84.970
4	14	0.0	0.0	0.263E+00	81.617
4	15	0.0	0.0	0.253E+00	78.488
4	16	0.0	0.0	0.244E+00	75.479
4	17	0.0	0.0	0.234E+00	72.585
4	18	0.0	0.0	0.225E+00	69.803
4	19	0.0	0.0	0.217E+00	67.127
4	20	0.0	0.0	0.208E+00	64.553
4	21	0.0	0.0	0.200E+00	62.079
4	22	0.0	0.0	0.193E+00	59.699
4	23	0.0	0.0	0.185E+00	57.410
4	24	0.0	0.0	0.178E+00	55.209
5	1	0.0	0.0	0.171E+00	53.093
5	2	0.0	0.0	0.165E+00	51.057
5	3	0.0	0.0	0.158E+00	49.100
5	4	0.0	0.0	0.152E+00	47.218
5	5	0.0	0.0	0.147E+00	45.408
5	6	0.0	0.0	0.141E+00	43.667
5	7	0.0	0.0	0.135E+00	41.993
5	8	0.0	0.0	0.130E+00	40.383
5	9	0.0	0.0	0.125E+00	38.835
5	10	0.0	0.0	0.120E+00	37.346
5	11	0.0	0.0	0.116E+00	35.914
5	12	0.0	0.0	0.111E+00	34.539
5	13	0.0	0.0	0.107E+00	33.214
5	14	0.0	0.0	0.103E+00	31.940
5	15	0.0	0.0	0.991E-01	30.716
5	16	0.0	0.0	0.953E-01	29.538
5	17	0.0	0.0	0.916E-01	28.406
5	18	0.0	0.0	0.881E-01	27.317
5	19	0.0	0.0	0.848E-01	26.270
5	20	0.0	0.0	0.815E-01	25.263
5	21	0.0	0.0	0.784E-01	24.294
5	22	0.0	0.0	0.754E-01	23.363
5	23	0.0	0.0	0.725E-01	22.467
5	24	0.0	0.0	0.697E-01	21.606
6	1	0.0	0.0	0.670E-01	20.778
6	2	0.0	0.0	0.645E-01	19.981
6	3	0.0	0.0	0.0	18.903
6	4	0.0	0.0	0.0	17.861
6	5	0.0	0.0	0.0	16.855
6	6	0.0	0.0	0.0	15.875
6	7	0.0	0.0	0.0	14.928
6	8	0.0	0.0	0.0	14.009
6	9	0.0	0.0	0.0	13.111
6	10	0.0	0.0	0.0	12.240
6	11	0.0	0.0	0.0	11.393
6	12	0.0	0.0	0.0	10.557
6	13	0.0	0.0	0.0	9.740
6	14	0.0	0.0	0.0	8.941
6	15	0.0	0.0	0.0	8.139
6	16	0.0	0.0	0.0	7.341
6	17	0.0	0.0	0.0	6.547
6	18	0.0	0.0	0.0	5.697
6	19	0.0	0.0	0.0	4.806
6	20	0.0	0.0	0.0	3.819
6	21	0.0	0.0	0.0	2.288
6	22	0.0	0.0	0.0	1.654
6	23	0.0	0.0	0.0	1.149
6	24	0.0	0.0	0.0	0.717
7	1	0.0	0.0	0.0	0.338
7	2	0.0	0.0	0.0	0.0

Table I-15 UNIT HYDROGRAPH CALCULATION -UPPER MAE WONG DAM- Case 2 (2/2)

Table I-16 FLOOD DAMAGE TO AGRICULTURE IN LAT YAO DISTRICT, NAKHON SAWAN PROVINCE

No	Name of Sub-District (Tambon)	Village	Plant	Cultivated Area Before Flood (rai)	Cultivated Area Before Flood (ha)	Damage Area (rai)	Damage Area (ha)	Damage Area (%)	Remarks
1.	Lat Yao	14	rice	11,339	1,814	7,806	1,249	69	
2.	Nong Nom Wao	1	"	205	33	131	21	64	
3.	Nong Yao	9	"	9,971	1,595	6,534	1,045	66	
4.	Soi Lakosn	9	"	8,896	1,423	5,692	911	64	
5.	Wong Ma	11	"	4,257	681	2,831	453	67	
6.	Wang Nuang	8	"	5,194	831	3,272	524	63	Nov. 7-25 1981
7.	Nab Kae	6	"	2,993	479	2,155	345	72	
8.	Huai Nam Horm	9	"	23,200	3,712	14,327	2,292	62	
9.	Mae Wong	5	"	7,532	1,205	3,039	486	40	
10.	Wang Sarn	9	"	8,532	1,365	8,532	1,365	100	
11.	Mae Lae	8	"	17,951	2,872	14,688	2,350	82	
12.	Ban Sai	1	"	859	137	547	88	64	
	Sub-Total	90		100,929	16,149	71,554	11,449	71	
1.	Mae Lae	4	*	11,000	1,760	5,500	880	50	
2.	Mae Wong	3	*	9,200	1,472	4,600	736	50	
3.	Wang Sarn	3	*	9,200	1,472	4,600	736	50	
4.	Wang Ma	3	*	9,000	1,440	4,500	720	50	
5.	Wang Muang	3	*	6,500	1,040	3,250	520	50	
6.	Nab Kae	4	*	6,600	1,056	3,300	528	50	
7.	Soi Lakom	4	*	5,800	928	2,900	464	50	
8.	Huai Nam Horm	4	*	16,300	2,608	8,100	1,296	50	Oct. 10-22 1983
9.	Lat Yao	12	*	11,600	1,856	5,800	928	50	
10.	Nong Nom Wao	5	*	7,500	1,200	3,750	600	50	
11.	Nong Yao	4	*	9,100	1,456	4,550	728	50	* rice, mung bean
12.	Noen Kee Lek	2	*	3,200	512	1,600	256	50	
13.	Ban Sai	2	*	1,300	208	650	104	50	
	Sub-Total	52		106,300	17,008	93,100	14,896	50	

Source: Agricultural Office of Lat Yao District, Nakhon Sawan Province

Table I-17 FLOOD DAMAGES IN UTHAI THANI PROVINCE (1/2)

Nov. 8 - 20, 1981

District (Ampho)		Uthai Thani	Nong Kya Yang	Nong Chang	Thap Than	Sawang Arom	Ban Rai	Lan Sak	Highway	Total
Flooding Area	Sub-District (Tambon)	13	9	10	10	4	7	3	-	56
	Village (Ban)	65	49	46	83	28	32	26	-	329
Damage to People	Total Household	1	-	692	2,323	943	228	1,233	-	5,420
	Total Population	2	-	3,218	9,815	3,171	824	6,068	-	23,098
	Dead	1	-	-	-	-	-	3	-	4
	Injured	-	-	-	-	-	-	-	-	-
	Missing	-	-	-	-	-	-	-	-	-
Number of Damaged Households	Totally Damaged	1	-	-	16	-	-	36	-	53
	Partially Damanged	-	-	-	-	-	-	3	-	3
Flooded Farmland	Rice (Rai)	12,213	34,281	7,297	139,775	17,128	2,495	11,672	-	224,861
	Rice (ha)	1,954	5,485	1,168	22,364	2,740	399	1,868		35,978
	Crop (Rai)	965	-	10	54,150	4,936	13,972	12,243	-	86,276
	Crop (ha)	154	-	2	8,664	790	2,236	1,959		13,804
Damaged Farmland	Rice (Rai)	12,213	3,100	7,297	5,814	9,856	1,578	8,080	-	47,938
	Rice (ha)	1,954	496	1,168	930	1,577	252	1,293		7,670
	Crop (Rai)	965	-	10	2	3,136	9,530	8,418	-	22,061
	Crop (ha)	154	-	2	0	502	1,525	1,347		3,530
Public Utility	Road Number	62	28	52	66	18	37	45	8	316
	Road Distance (km)	69.3	14.4	137.8	156.8	88	93.3	39.1	29.3	627.9
	Bridge	2	1	8	16	2	5	25		59
	Weir	27	-	1	19	-	3	5		55
	Government Office	1	-	-	-	-	-	-		1
	Temple	1	-	-	-	-	-	-		1
	Others	11	-	-	-	-	-	8		19
Livestock (Cattle, etc.)		54	-	-	-	-	7	75		136
Domestic Fowls (Chicken, etc.)		54,606	9,130	-	5,500	7,971	665	3,063		80,935

Data Source; Uthai Thani Provincial Office

Table I-17 FLOOD DAMAGES IN UTHAI THANI PROVINCE (2/2)

Au. 15 - Nov. 20, 1983

District (Ampho)			Uthai Thani	Nong Kya Yang	Nong Chang	Thap Than	Sawang Arom	Ban Rai	Lan Sak	Total
Flooding Area	Sub-District (Tambon)		12	8	8	30	4	8	3	54
	Village (Ban)		54	39	37	51	38	66	28	313
Damage to People (To be helped with consumer goods)	Total Household		3,207	-	1,085	1,259	4,175	-	2,830	12,559
	Total Population		17,173	-	2,584	5,454	21,437	-	8,945	55,593
	Dead		-	-	-	1	3	-	1	5
	Injured									
	Missing									
Number of Damanged Households			2	0	5	120	0	3	3	133
Flooded Farmland	Rice	(Rai)								
		(ha)								
	Crop	(Rai)								
		(ha)								
Damaged Farmland	Rice	(Rai)	42,354	10,967	7,705	16,168	29,623	24,294	20,083	151,194
		(ha)								
	Crop	(Rai)								
		(ha)								
Public Utility	Road	Number	44	10	21	35	27	68	26	251
		Distance (km)	127	3	13	17	100	40	71	370
	Bridge		1		1	2	3	33	9	50
	Weir			1	2			5	1	8
	Government Office									
	Temple									
	Others									
Livestock (Cattle, etc.)			16	0	0	0	62	7	6	91
Domestic Fowls (Chicken, etc.)			3,017	0	0	0	9,042	323	1,842	14,224

Source: See Ref. 3

Table I-18 FLOOD CONTROL BY RESERVOIR
UPPER MAE WONG DAM C.A. 612 Km^2

Year	Reservoir Inflow	Outlet for Irrigation	Spillout	Maximum & Second Maximum Flood			
				Without Reservoir	With Reservoir	Without Reservoir	With Reservoir
	(10^3 m^3)	(10^3 m^3)	(10^3 m^3)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
1954	186,570	158,271	75,389	35.5	35.1	35.1	34.4
1955	180,776	193,279	2,072	29.3	2.4	28.3	-
1956	196,781	144,626	0	27.9	-	27.0	-
1957	275,353	96,354	151,228	48.4	48.0	45.2	44.8
1958	221,851	170,294	50,161	39.0	34.1	35.1	17.6
1959	230,936	120,083	96,106	39.9	39.4	34.5	31.3
1960	169,826	174,190	0	28.8	-	25.0	-
1961	232,091	120,114	68,411	27.8	26.5	26.6	23.8
1962	218,252	138,071	76,718	39.6	39.2	38.1	28.9
1963	230,919	115,113	56,839	41.8	28.1	38.7	19.1
1964	309,768	60,024	231,020	45.5	45.1	45.1	44.7
1965	195,743	152,539	44,942	29.8	24.3	26.5	14.5
1966	182,081	163,908	0	22.6	-	20.6	-
1967	123,339	301,460	0	18.9	-	17.5	-
1968	135,804	144,536	0	18.4	-	17.0	-
1969	155,223	114,035	0	29.0	-	16.9	-
1970	259,108	150,096	0	34.6	-	32.6	-
1971	195,740	188,611	0	46.9	-	24.1	-
1972	252,293	172,535	0	43.3	-	42.2	-
1973	239,414	213,530	0	42.6	-	41.8	-
1974	376,448	92,700	242,150	93.8	93.3	80.7	32.8
1975	236,002	137,644	80,978	43.3	17.4	30.1	16.0
1976	215,393	200,379	13,099	59.6	12.5	29.4	0.9
1977	57,336	263,273	0	11.3	-	7.7	-
1978	221,867	127,827	0	65.9	-	36.3	-
1979	182,122	222,301	0	64.5	-	26.3	-
1980	282,828	134,009	0	108.8	-	40.5	-
1981	204,075	165,131	0	38.8	-	29.4	-
1982	108,338	279,883	0	19.4	-	16.3	-
Mean	209,526	162,580	41,004	41.2	15.4	31.5	10.6

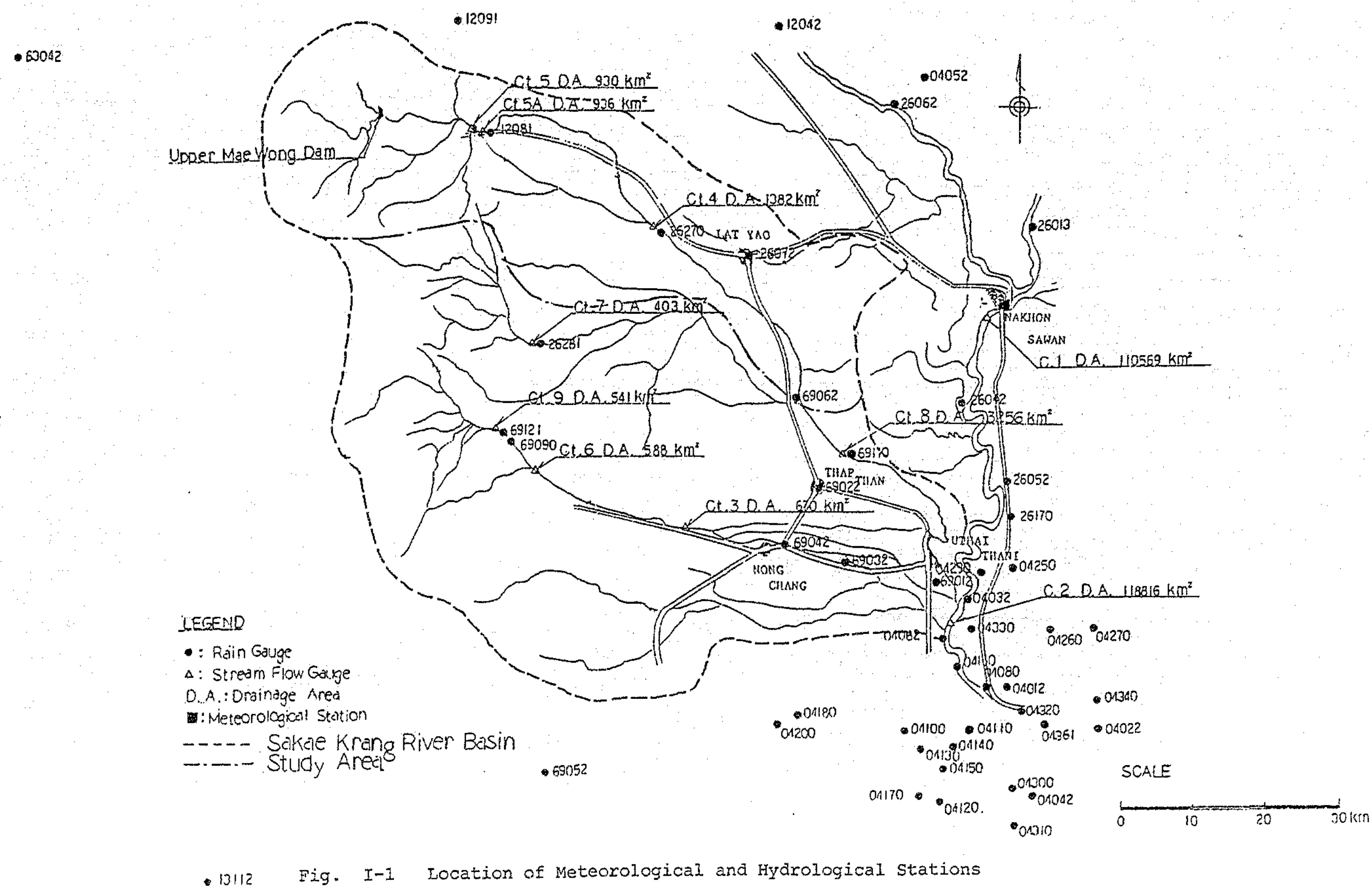


Fig. I-1 Location of Meteorological and Hydrological Stations

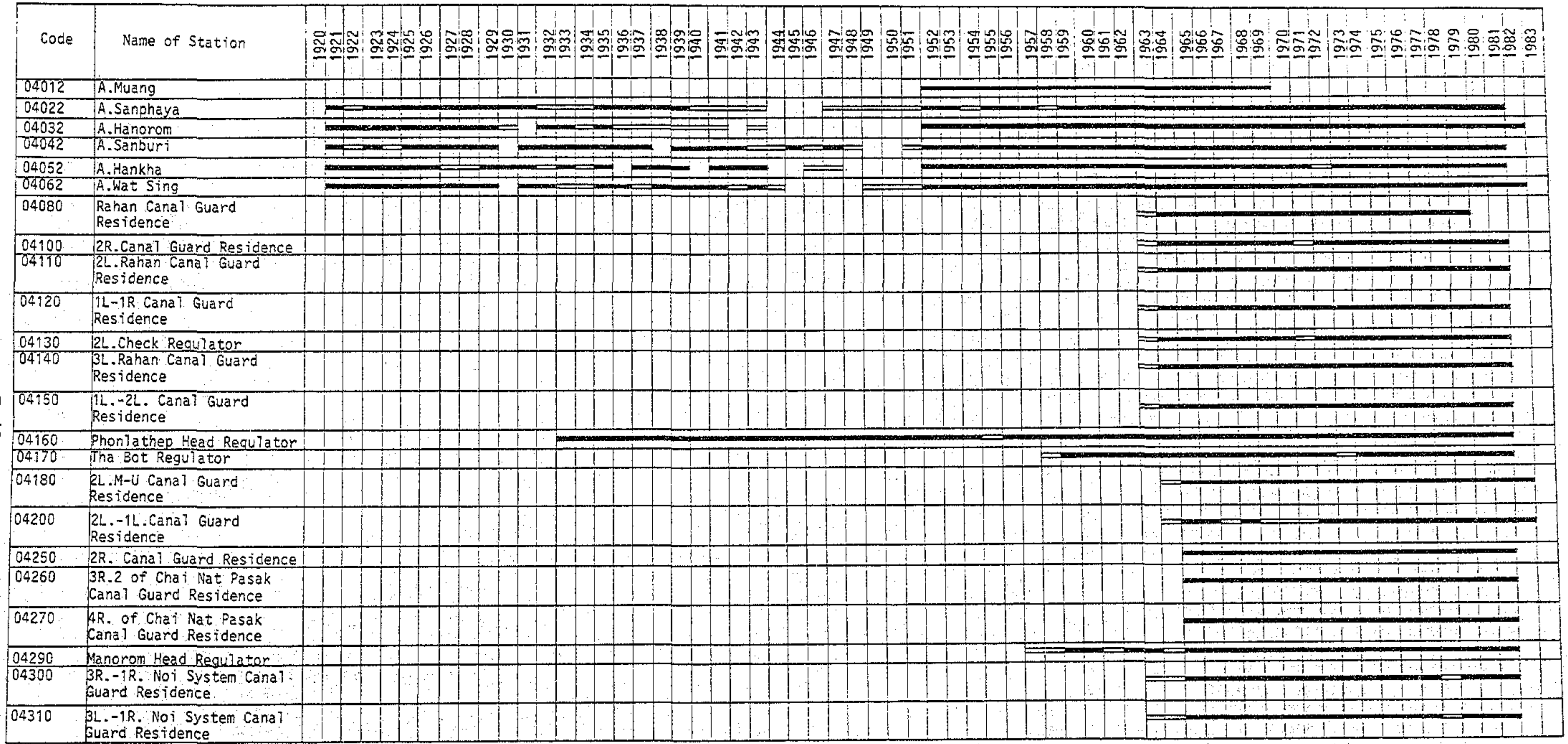


Fig. I-2 Rainage Station and Period of Observation (1/2)

: Observation with Lack of Data

: Observation without Lack of Data

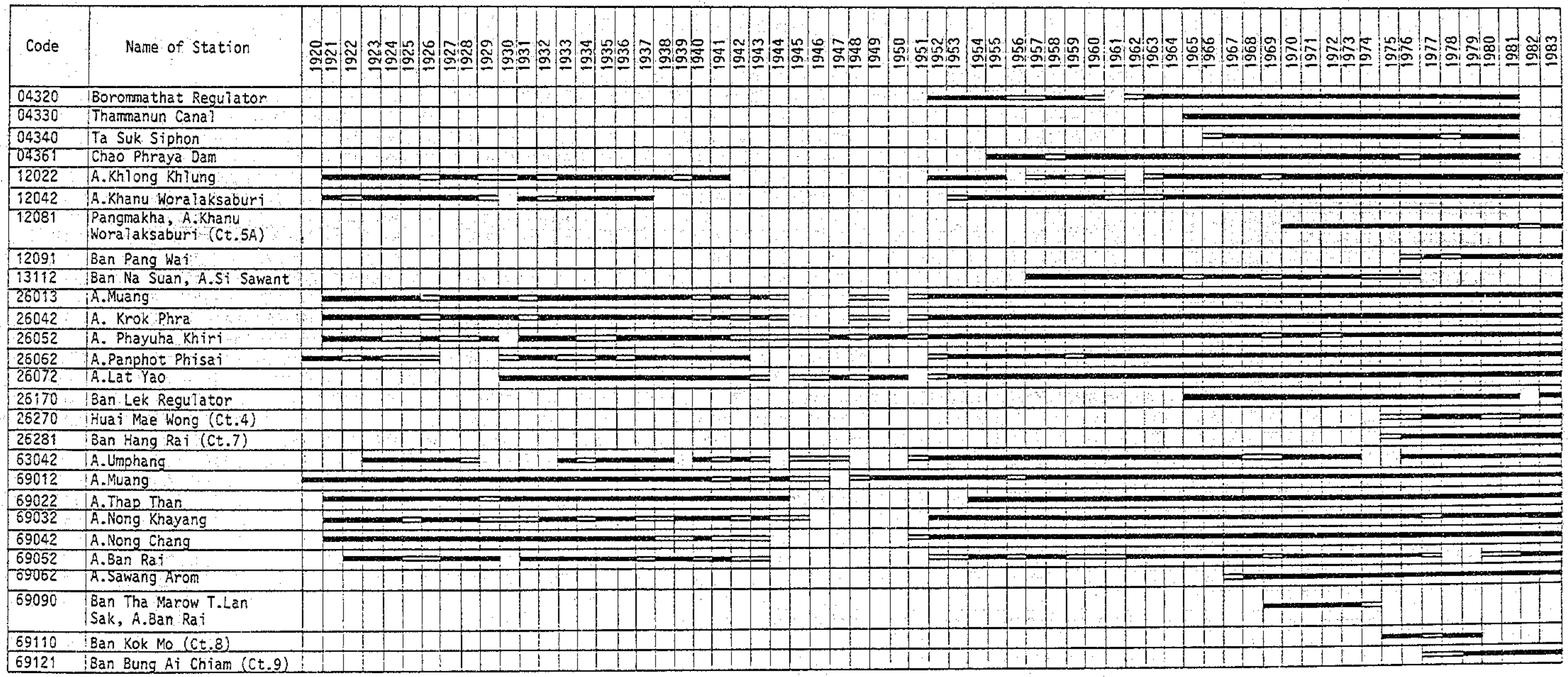


Fig. I-2 Rainage Station and Period of Observation (2/2)

: Observation with Lack of Data
: Observation without Lack of Data

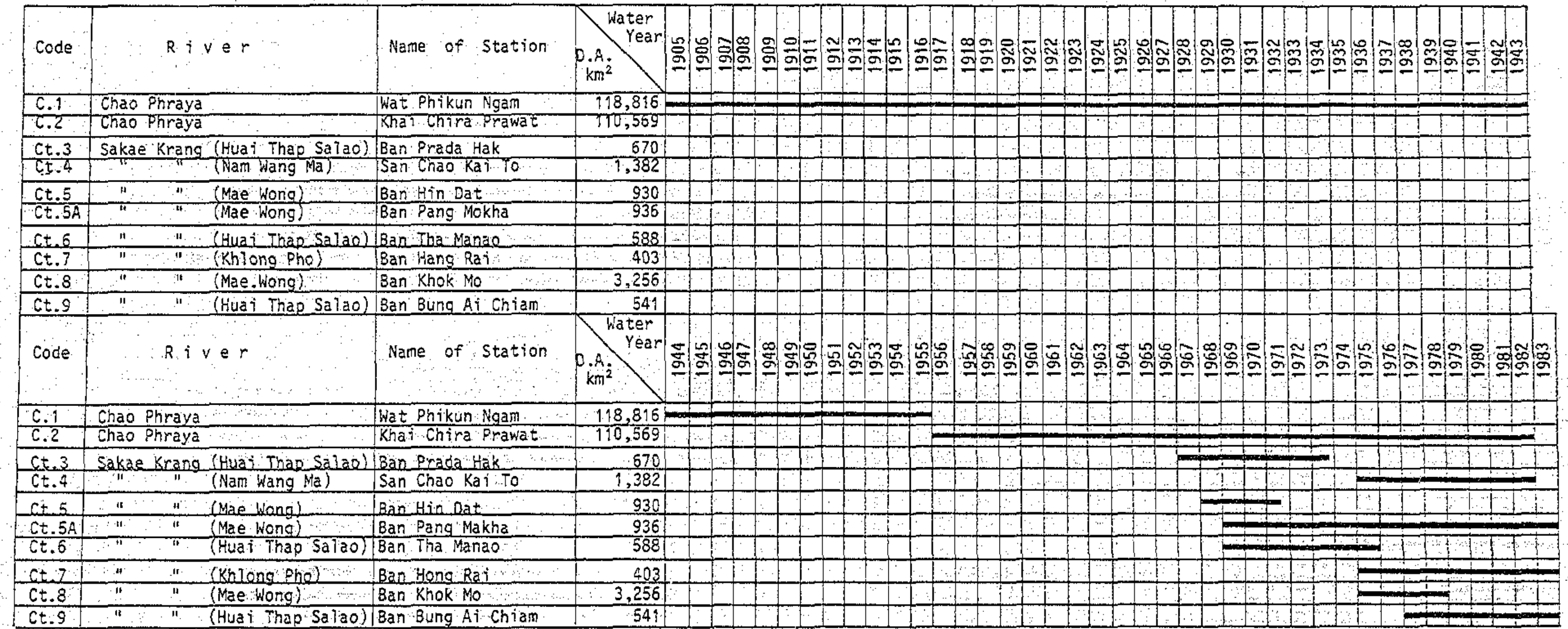


Fig. I-3 Stream Gaging Station and Period of Observation

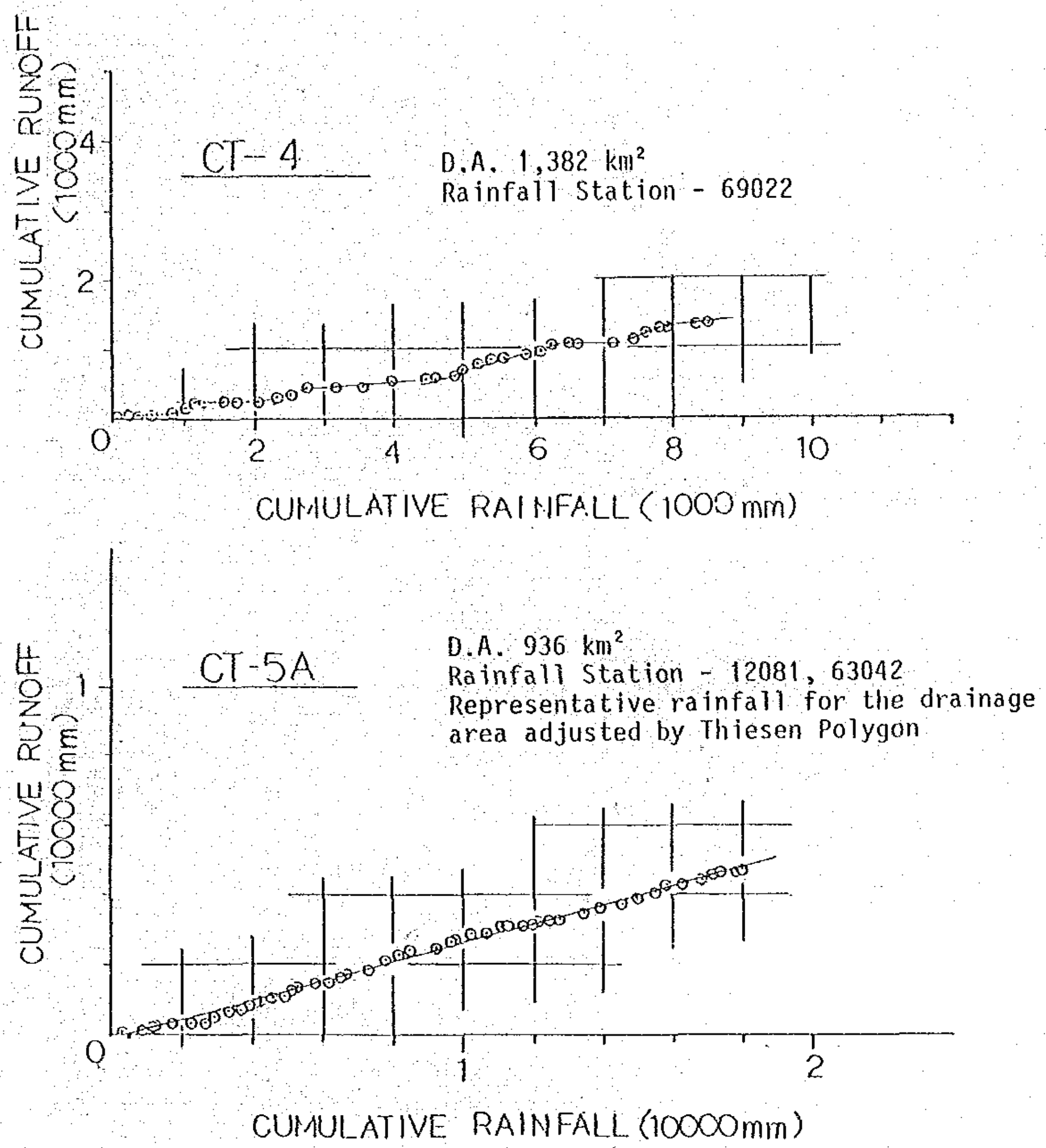


Fig. I-4 Double Mass Curve for Runoff and Rainfall

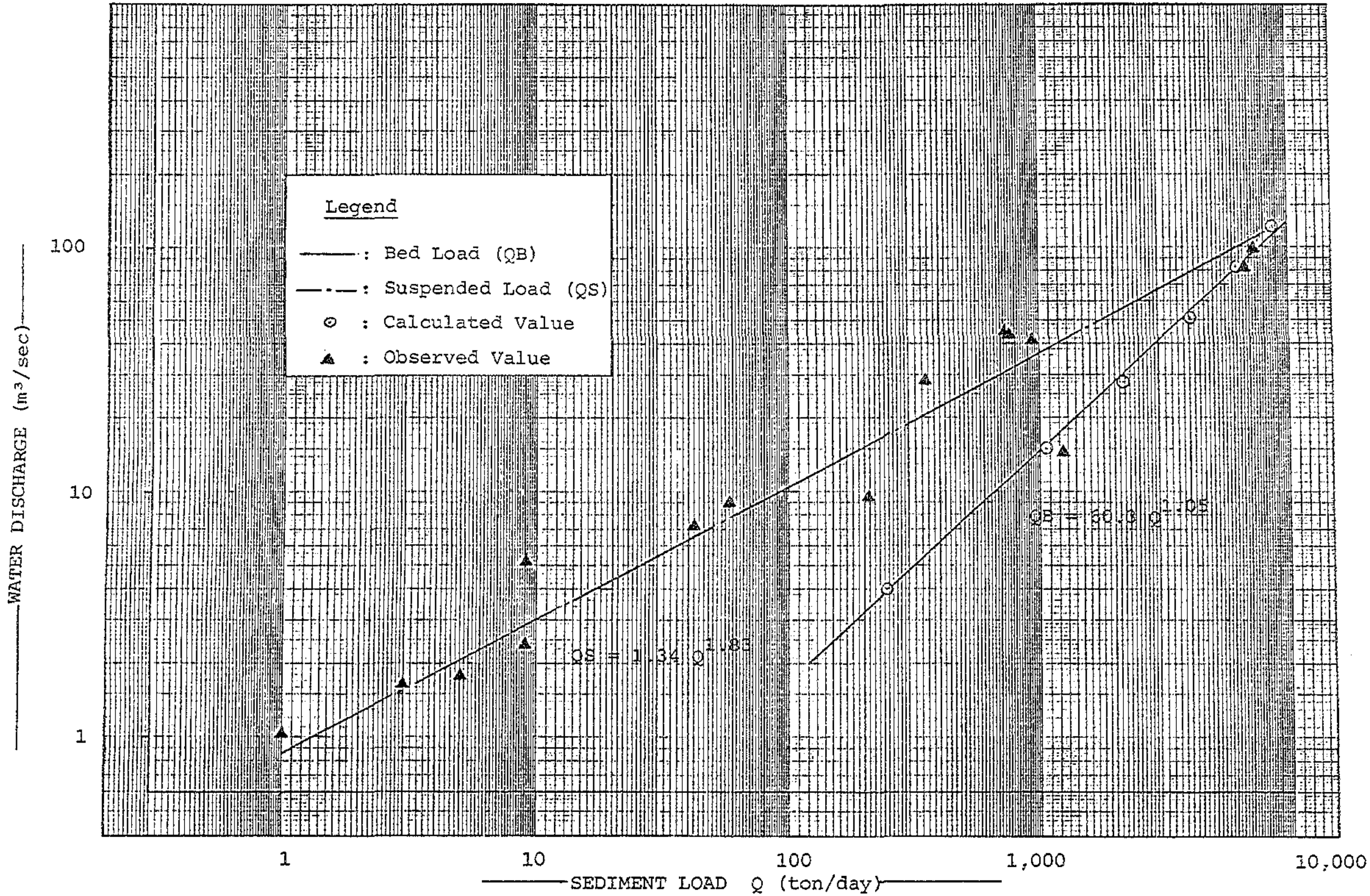


Fig. I-5 Sediment Load Distribution

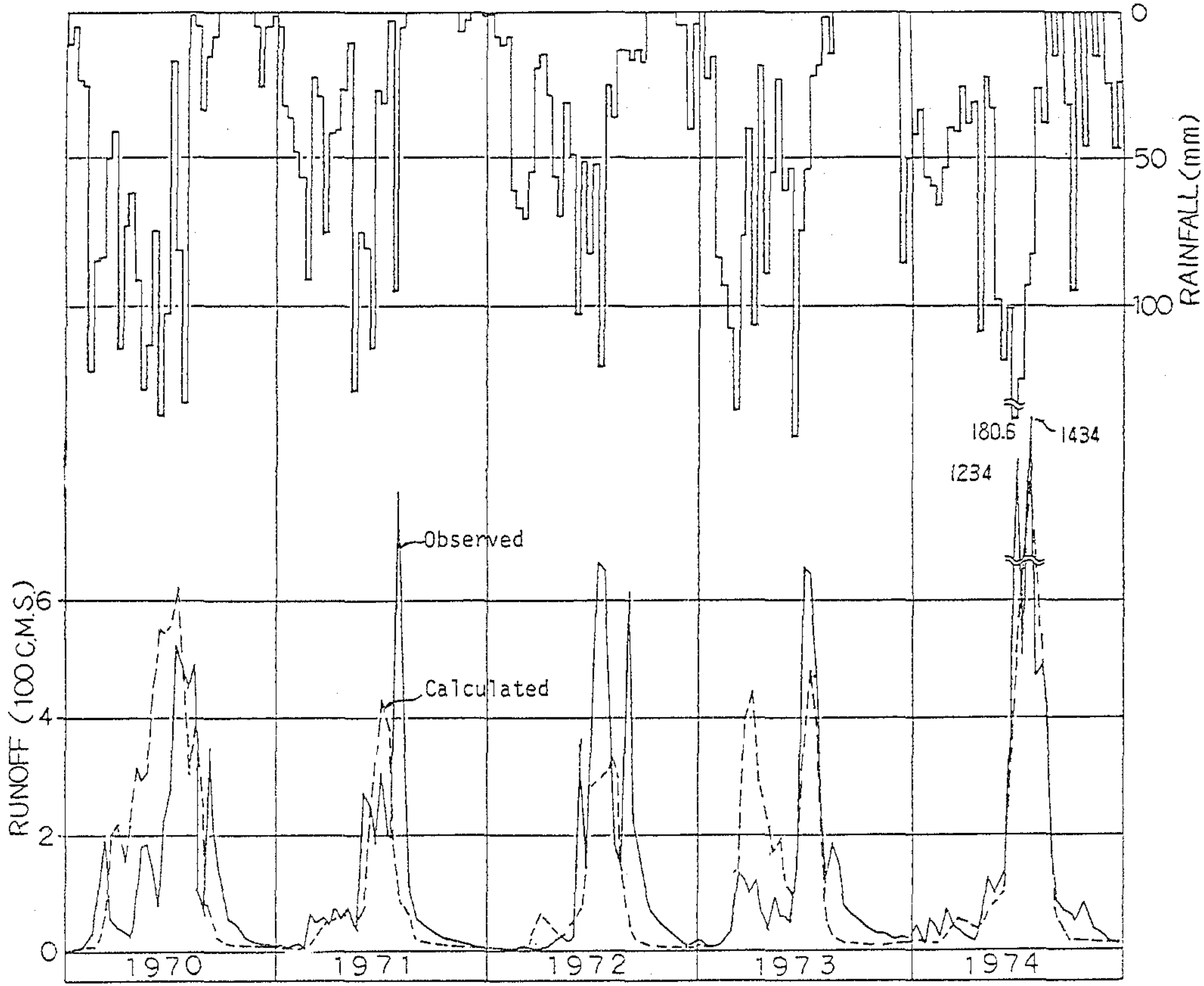


Fig. I-6 Runoff Simulation by Tank Model at CT-5A (1/3)

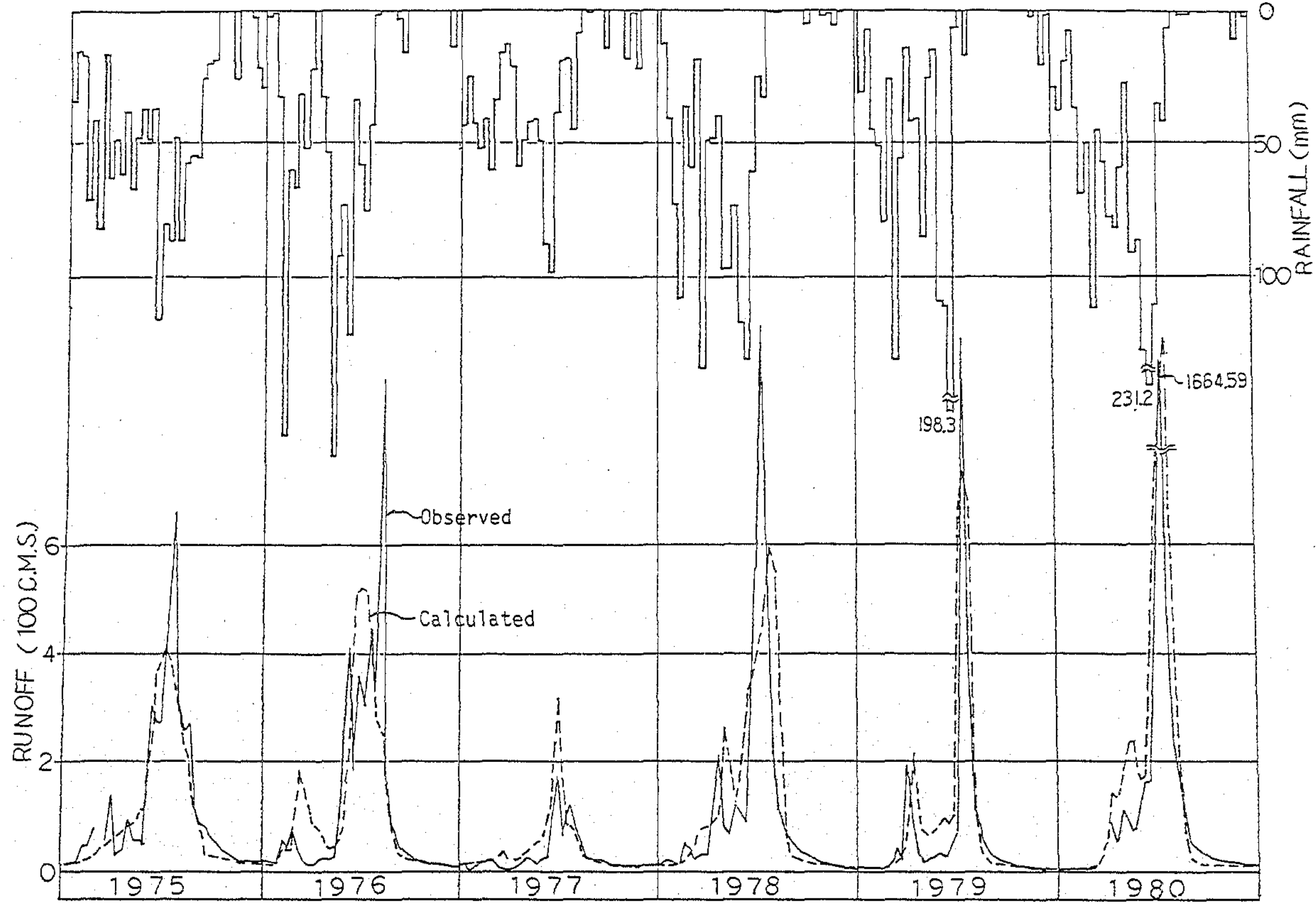


Fig. I-6 Runoff Simulation by Tank Model at CT-5A (2/3)

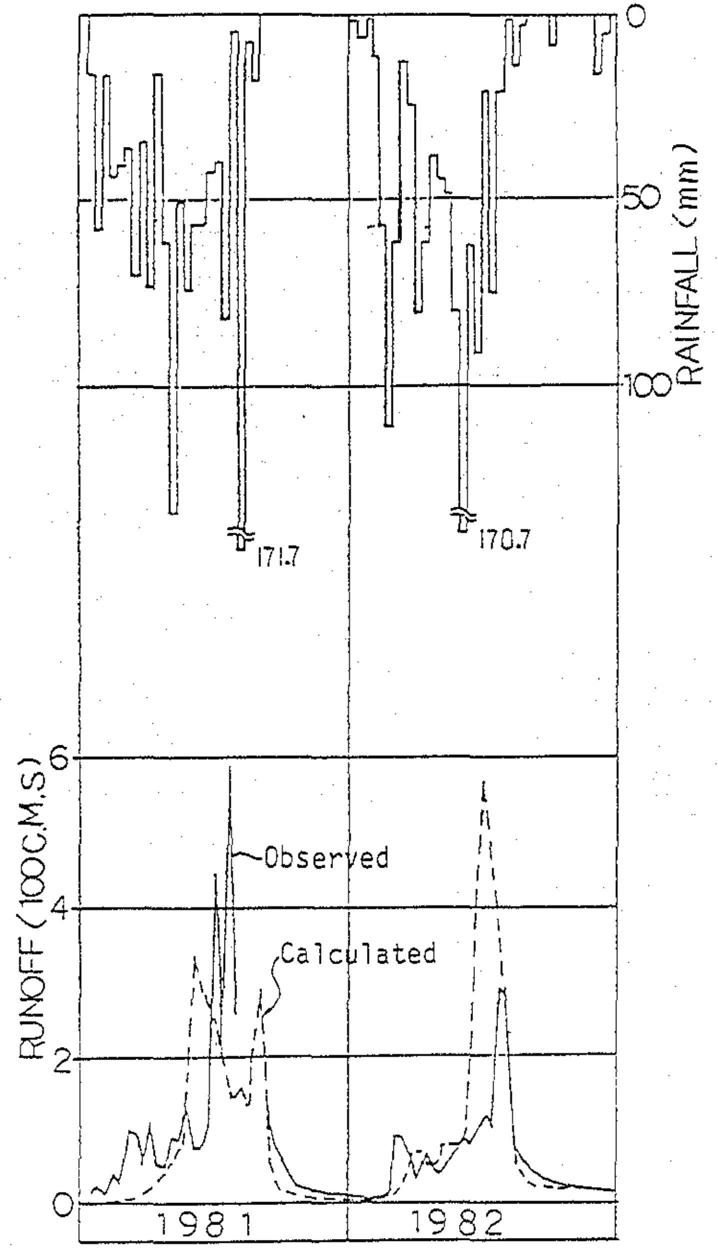


Fig. I-6 Runoff Simulation by Tank Model at CT-5A (3/3)

CT-5A

Catchment Area : 936 km^2

First Storage Height

First Tank	0 mm
Second Tank	0 mm
Third Tank	0 mm
Fourth Tank	300 mm

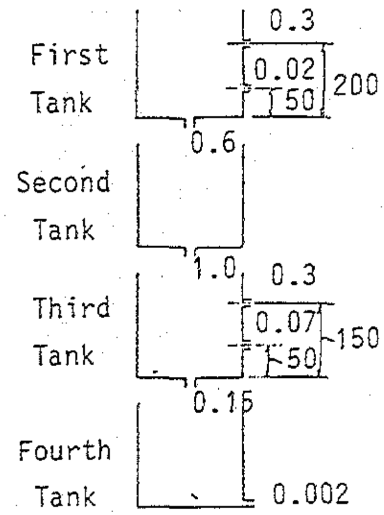


Fig. I-7 Tank Model Dimension

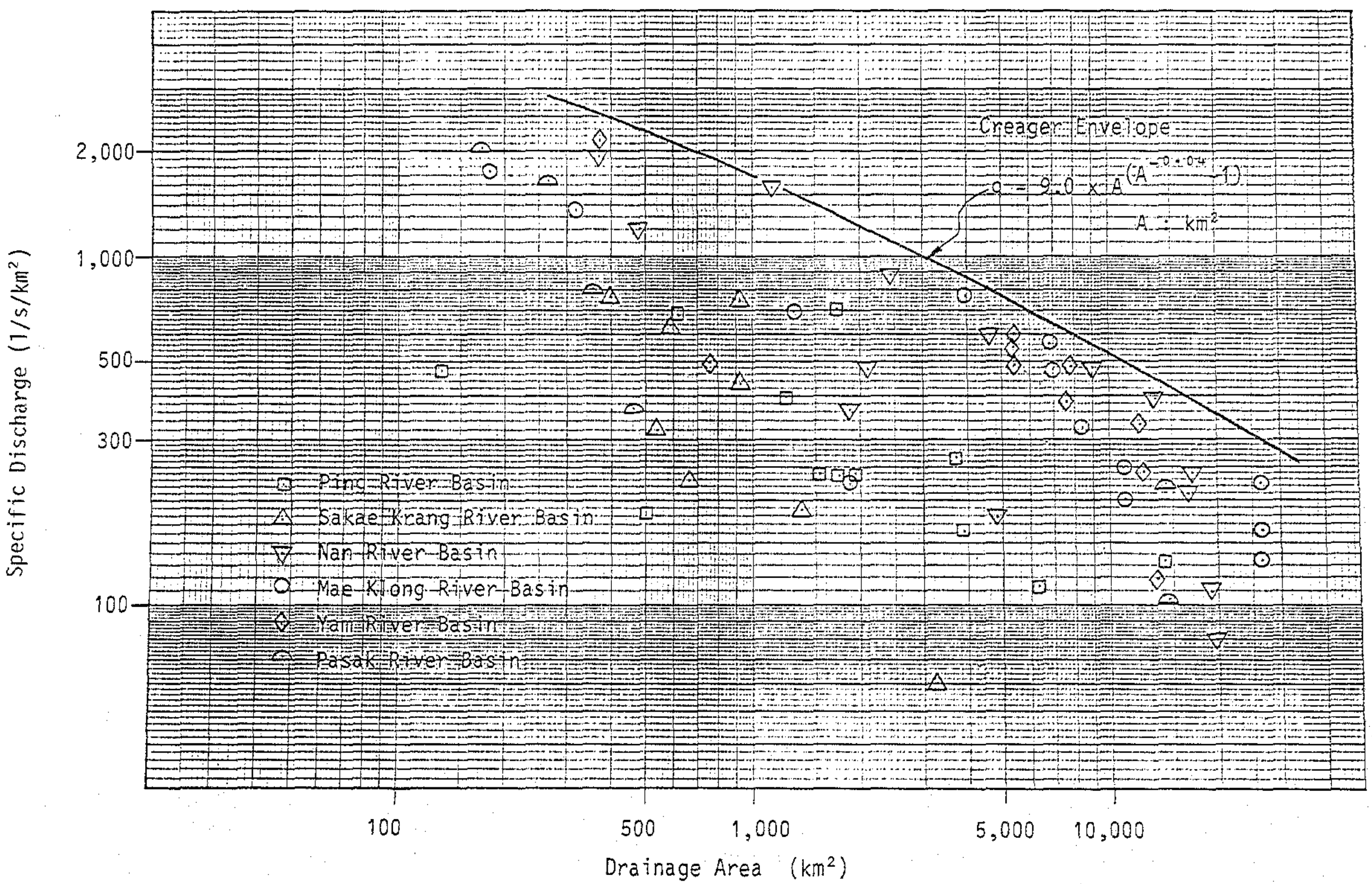


Fig. I - 8 Creager Envelope

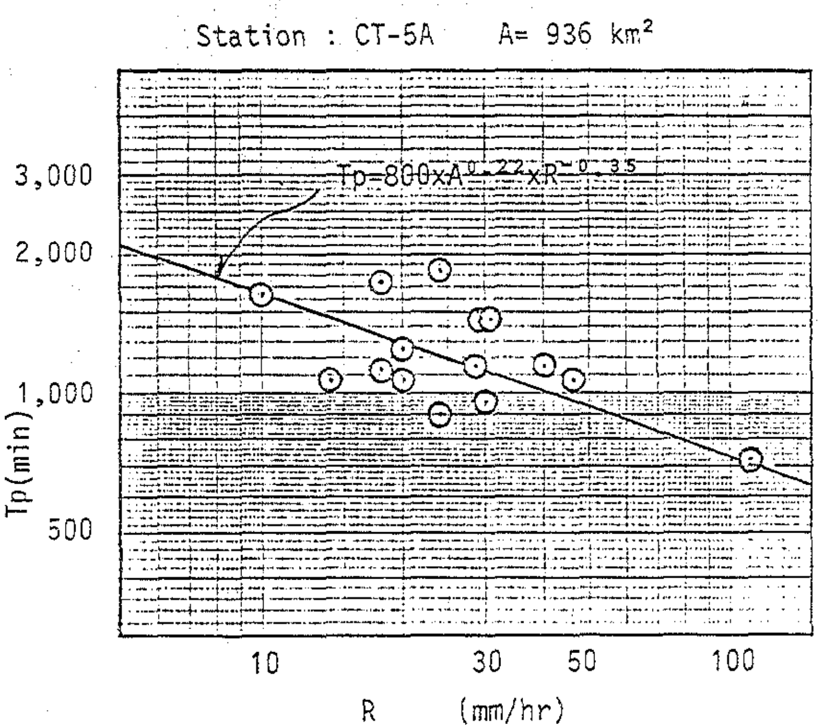
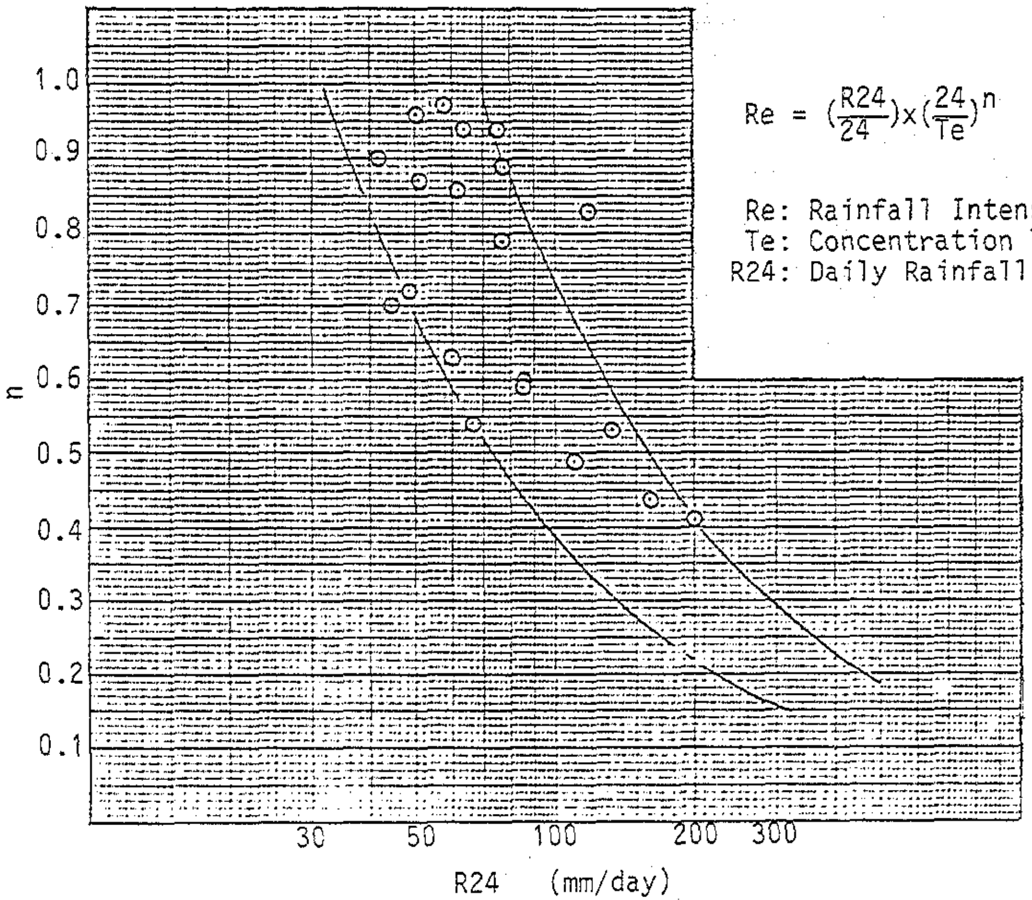


Fig. I-9 Runoff Concentration Time and Rainfall Intensity



$$Re = \left(\frac{R24}{24}\right) \times \left(\frac{24}{Te}\right)^{n}$$

Re: Rainfall Intensity (mm/hr)
Te: Concentration Time (hr)
R24: Daily Rainfall (mm/day)

Fig. I-10 Relation Between R24 and n

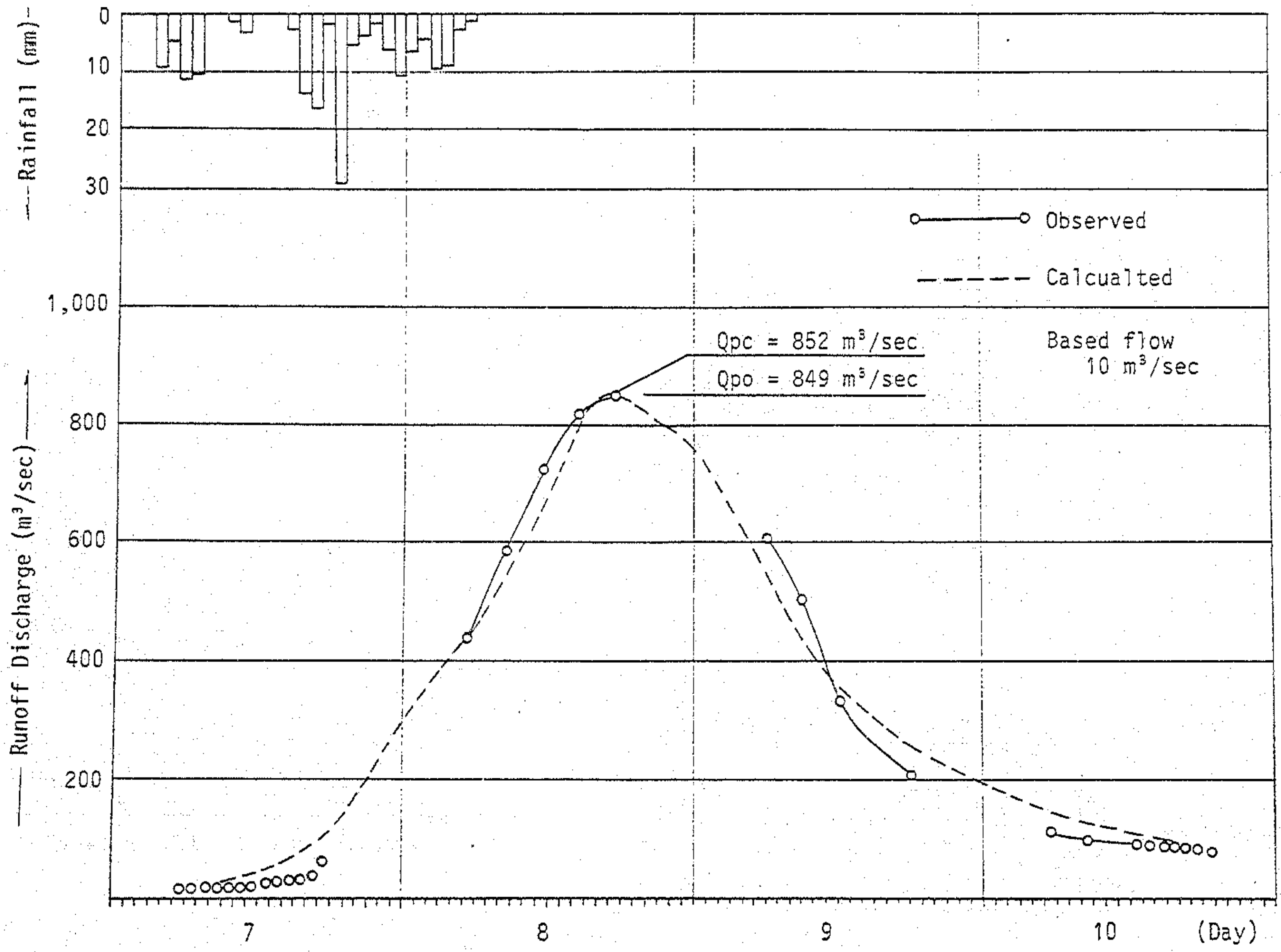


Fig. I-11 Unit Hydrograph Simulation

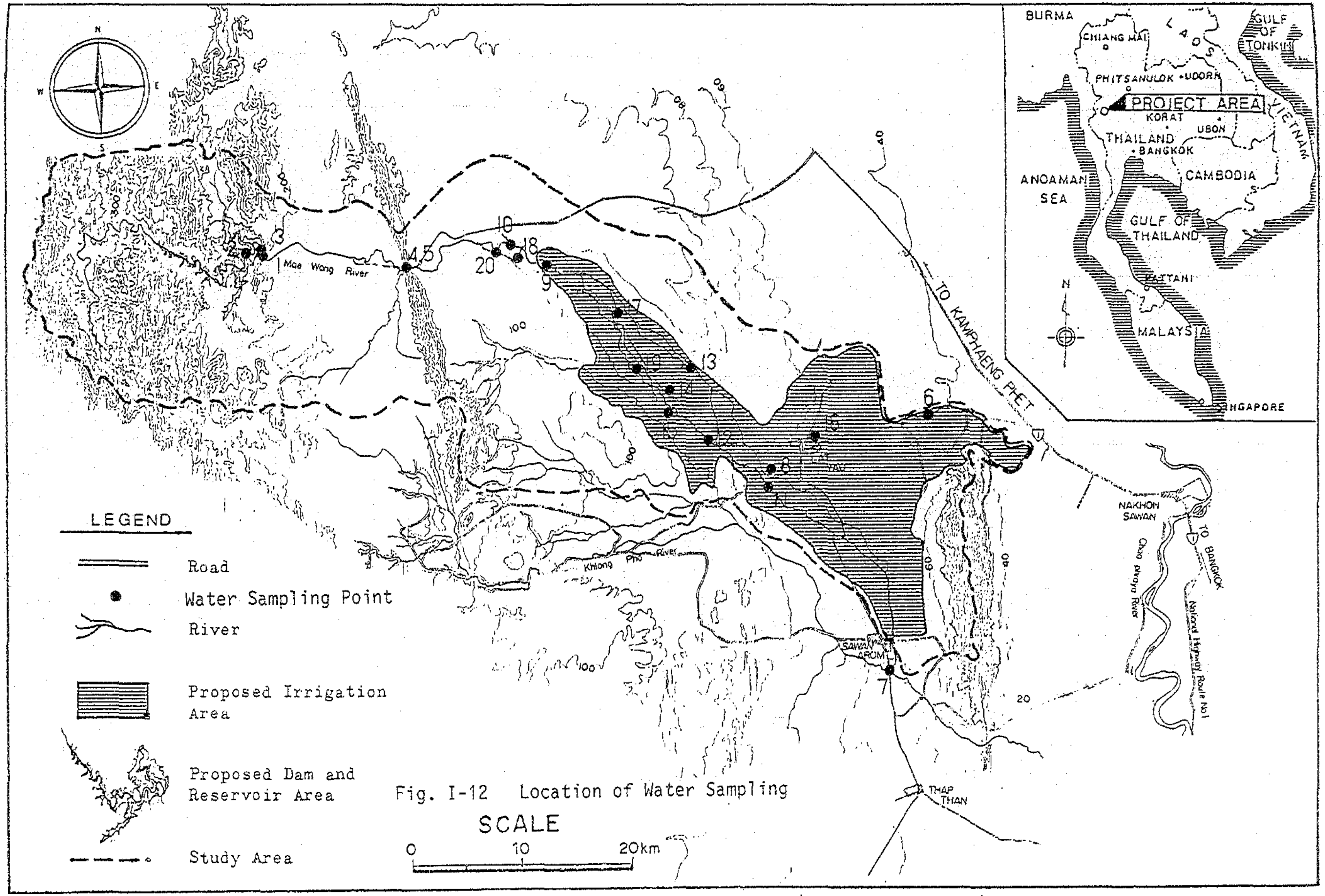


Fig. I-12 Location of Water Sampling

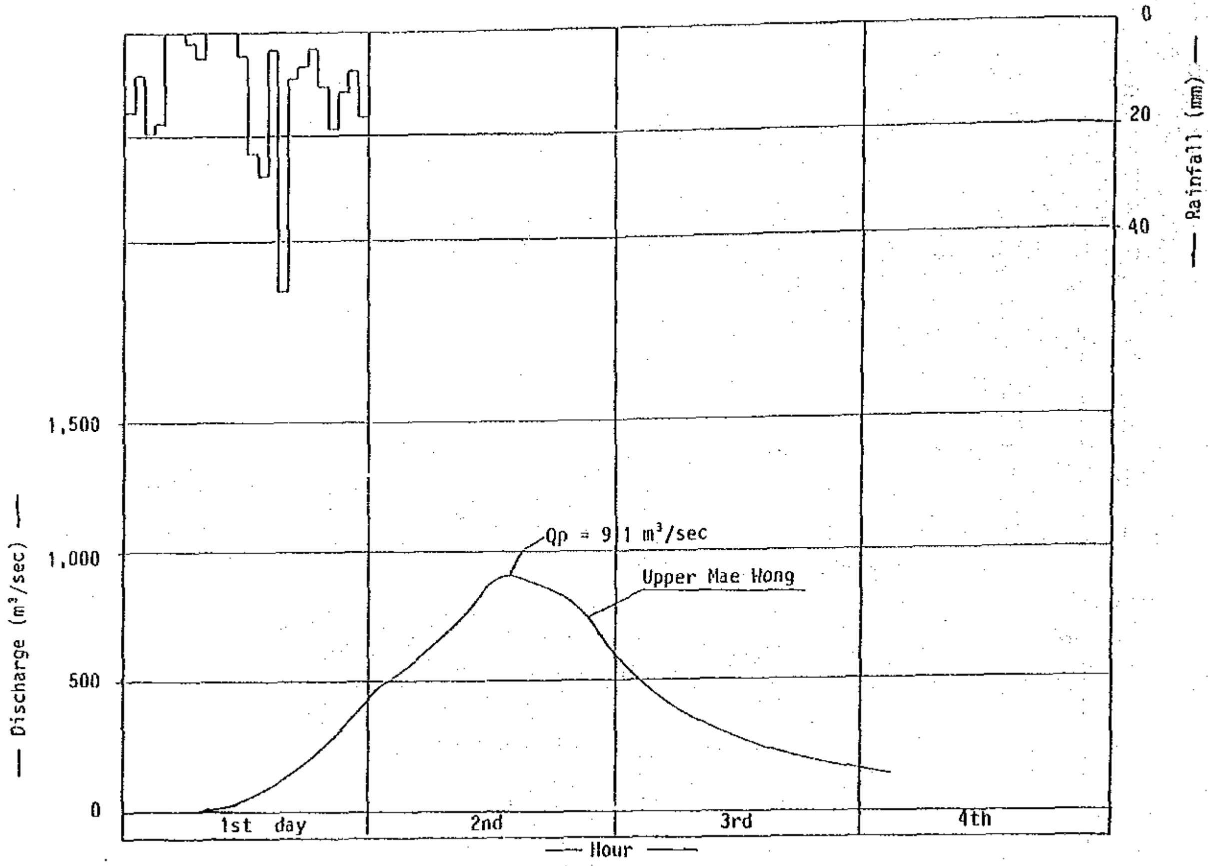


Fig. I-13 Flood by Unit Hydrograph (Case 1) (1/2)

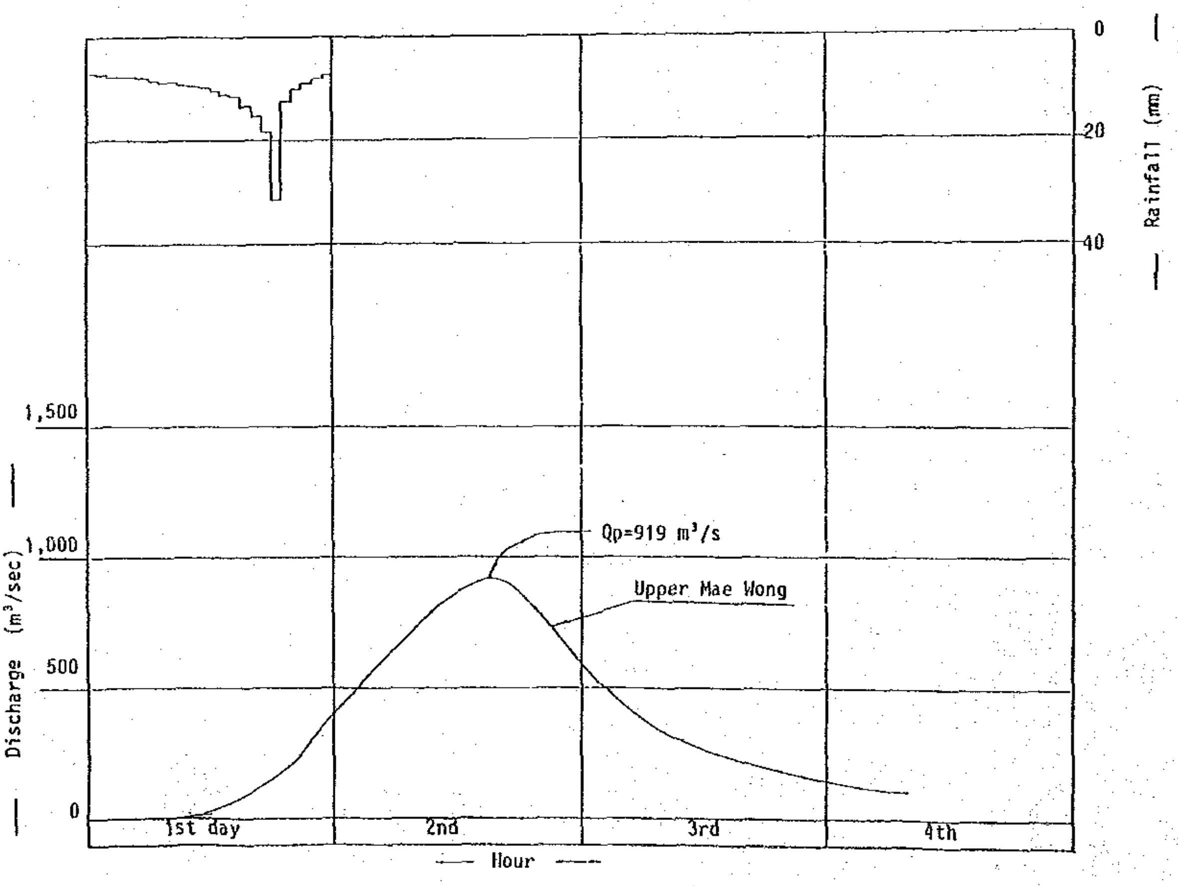


Fig. I-13 Flood by Unit Hydrograph (Case 2) (2/2)

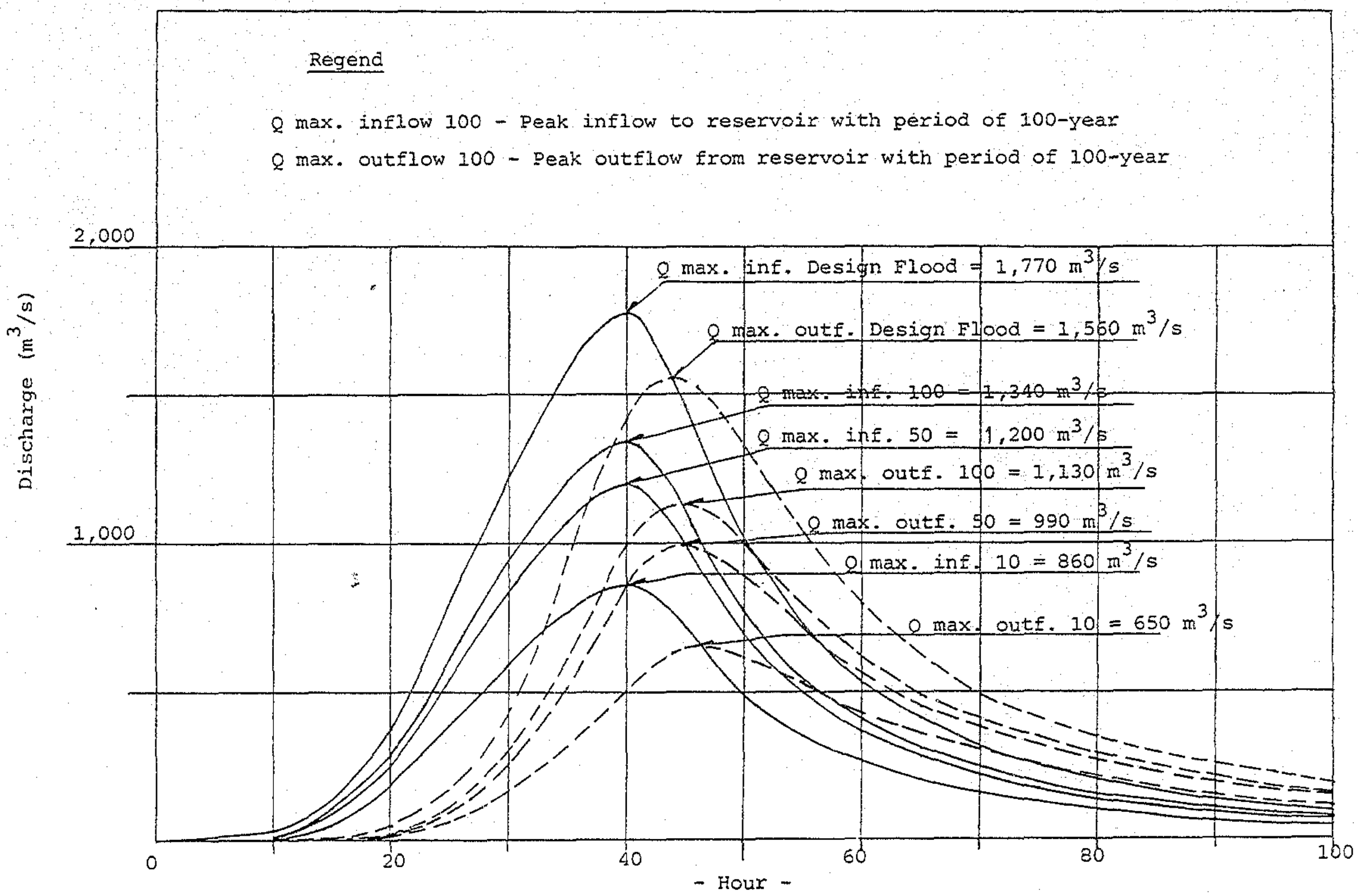


Fig. I-14 Flood Routing Curve

ANNEX–II
GEOLOGY AND EMBANKMENT MATERIALS

ANNEX - II

GEOLOGY AND EMBANKMENT MATERIALS

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GEOLOGY AND EMBANKMENT MATERIALS

1. GEOLOGY

1.1 Basin Geology

The Mae Wong river basin is geologically divided roughly into two parts; the western Paleozoic zone and the eastern Mesozoic part by a Tertiary volcanic belt running along latitude of about E-99°-30', or along the Khao Chonkan mountain ranges.

The irrigation area is located within the eastern Mesozoic part, in which a vast Khorat Plateau develops, having a more gentle, almost flat, geostructure.

The proposed Upper Mae Wong damsite and reservoir are located within the western Paleozoic zone which has a distinct N-S geological structure, suffering the Burmese-Malaya geosynclinal movement of meridional trend. These geostructural modes are thought to have been formed as a result of the crustral movements during the Mesozoic and Tertiary periods.

The geologic chronology is shown in Fig. II-1. Major geologic features of reservoir and damsite are Uthai Thani complexes of Proterozoic precambrian quartzite, calc-silicate and schist, Plaeozoic to Cambrian quartzite, phillite and schist, and Mesozoic granite groups intruding or pushing into the said old rocks. General geologic map is shown in Fig. II-2.

1.2 Reservoir Geology

The reservoir area of the proposed Upper Mae Wong dam is geologically formed by granite groups of granite, diorite and gabbro. These rocks are massive to gneissic and quartzose to felsic. Predominant rocks are granite gneiss along the Mae Wong river in the reservoir, feldspathic granite at downstream of damsite, schistose granite at damsite and quartzose granite at upstream left bank.

The direction of schistosity of these granite groups is about N 20°E. The Mae Wong river course is largely winding because the river runs against the geological schistosity. Dissolvable limestone groups are not expected in the reservoir geology.

The reservoir geology shows a final stage of geologic history and forms a gentle and stable topography. Landslide or active movement of topography would not be expected.

A geologic fault was found along the lineament crossing the reservoir from northeast to southwest about 1.5 km upstream of damsite. The fault was also observed with boring No. 8 located at the proposed emergency spillway site. Disturbance of boring core between 22.4 m and 25.7 m in depth from the ground surface are considered to have been formed by the fault movement. The fault would be expected small in scale and old. No special treatment would be required for dam and reservoir construction to prevent seepage.

1.3 Damsite Geology

1.3.1 General

The geology of the proposed damsite is predominated by green rocks which belong to the Precambrian Uthai Thani complexes. These green rocks are composed of Quartzite, Calc-silicate rocks and Schist. Boundary of these rocks are transitional and partly alternated. General characteristics of rocks are summarized as follows:

		Quartzite	Calc-silicate	Schist
1.	Color		- Greenish Grey -	
2.	Schistosity	Massive	Massive	Weak
3.	Hardness	Very Hard	Hard	Hard to Medium
4.	Rock Surface	Cracky	Sound	Slightly to Medium Weathered
5.	Component	Silica	Siliceous Calcareous	Siliceous Calcareous Micaceous

(1) Outcrop condition of rock

The quartzite outcrop is found widely but outcrops of calc-silicate and schist are rare. Along the riverbed, outcrops of rocks are scattered and boulder and sand are deposited in the cracks or depression of rocks. Grabel distribution in the river deposit is relatively small.

(2) Structure

In the green rock group, the developments of quartz vein, calcite vein and silicification are remarkable but metamorphic grade of schist is low, chloritization is weak and serpentinization is rare. Granite group mainly schistose granite is also found within the green rocks. Schistosity strike investigated from outcrops and boring core is N 20° - 40°E and dip is 60° - 90°E but western strike was also found. This indicates a folding structure. Detailed investigation would be required.

(3) Schistose granite

Schistose granite is white grey in color, hard, medium grained and weak but massive in schistosity. It is outcropped in riverbed. The weathering of schistose granite would be generally thin about 2 - 3 m.

(4) River deposits

Fine sand originated from granite group is widely deposited along the river course. The depth of sand deposit is about 1 - 2 m but deep crack or erosion along the strike of calc-silicate or schist was found by boring core No. 3 in which the depth of crack is about 8 m from the surface.

(5) Talus deposit

Talus deposit around the damsite is generally thin, but partly 3 to 4 m at middle elevation of both abutments.

(6) Fault

The existence of lineament or fault was not found from the site investigation and the study on aerial photo. However, direction of ridges of both abutments is different at damsite and brecciate quartzite was found at riverbed, which would indicate some disturbances in geological formation crossing the dam axis. The fault scale, if existing, would be small and no treatment would be required other than ordinary grouting beneath the core trench.

(7) Groundwater

Groundwater levels found in the boring holes are very low and both abutment ridges from relatively thin mountain. Groundwater level would be assumed to be near to the riverwater level.

1.4 Geological Investigation

1.4.1 General

A geological investigation of the damsite and the reservoir area was carried out to determine the soundness of the site and the water tight qualities of the reservoir. Twelve holes, including percolation tests and standard penetration tests, were drilled to a total depth of 297.95 m. Rock was drilled by diamond bits of Nwm and Bwm with double core tube. Locations are shown in Fig. II-2. Drilling investigations were operated by RID from March 10 to May 31, 1985. It is summarized as follows:

Boring

Boring No.	Location	Drilled Depth (m)	Percolation Test (No)	Penetration Test (No)
1.	Left abutment	33.0	7	1
2.	Left abutment	34.0	10	4
3.	Left riverbed	50.0	9	0
4.	Riverbed center	36.5	7	0
5.	Right abutment	35.0	6	0
6.	Right abutment	30.0	5	0
7.	——	-	-	-
8.	Emergency spillway	31.0	9	4
9.	Quarry site No. 1	19.0	-	3
10.	Quarry site No. 2	20.0	-	2
11.	Core borrow area	3.15	-	6
12.	Core borrow area	3.15	-	6
13.	Core borrow area	3.15	-	3
	Total	297.95	53	29

Auger Boring

No.	Location	Drilled Depth (m)
AH1 - AH10	150 m upstream of dam axis	9.0
AH11 - AH21	Dam axis	10.1
AH22 - AH29	150 m downstream of dam axis	7.7
	Total	26.8

1.4.2 Water pressure test

Results of water pressure tests in the boring holes at damsite are summarized in Table II-1. The damsite foundation rocks within 5 to 10 m from the rock surface show semi-pervious permeability between 10 to 20 Lugion value at pressure level of about 2 kg/cm^2. This is considered because of development of cracks and seams at rock surface. Below this surface zone, the rock generally becomes water tight having Lugion value less than 5 at more than 7 kg/cm^2 of pressure level. At boring hole B-1 on the left abutment, relatively large Lugion values of 10 to 20 are recorded to the depth up to 23 m from the ground surface. On the right abutment at boring hole B-6, large Lugion value over 30 was recorded in the rock surface zone up to 15 m from its surface. At the other boring holes, water pressure tests resulted less permeability and foundation rocks are considered to be quite water tight except surface zone.

Usually dam foundation is requested to have water tightness at less than 5 of Lugion value to protect the dam foundation against hydraulic failure. Foundation grouting will be necessary to improve the surface cracky zone of foundation rocks.

1.4.3 Standard penetration test

Standard penetration tests were conducted except rock portion in the boring holes. The results are summarized as follows:

Boring No.	Depth (m)	N-Value	Remarks
B-1	1.0 - 1.3	4	Talus deposit
B-2	5.0 - 5.3	50	River deposit
	6.0 - 6.3	50	River deposit
	7.0 - 7.3	50	River deposit
	8.0 - 8.1	50/10	River deposit
B-8	1.0 - 1.3	35	Talus deposit
	2.0 - 2.25	50/25	Talus deposit
	3.0 - 3.15	50/15	Talus deposit
	4.0 - 4.1	50/10	Talus deposit

1.4.4 Rock property

Physical property tests were conducted on the samples taken from the boring core. The results show that all rock samples of quartzite, calc-silicate and schist have sound and good quality. Specific gravity at SSD condition is ranging between 2.6 and 2.7 and water absorption ratio is less than 1.0%. Compression test, however, shows relatively smaller values of about 100 to 500 kg/cm^2. This is considered because of existence of hair-cracks and the test results will not express the true value of rock strength. The test results are summarized as follows:

Test No.	Boring No.	Sampling Depth (m)	Name of Rock	Classi-fication	Remarks
1	B-1	6.0 - 6.2	Qz	B	Lamina plane minor
8	B-1	11.6 - 11.8	Qz	B	Parting dip; 72.4°
6	B-2	15.5 - 15.65	Qz	B	Parting dip; 70°
9	B-3	14.9 - 15.15	C-S	CH	Lamina plane, banded pyrite
5	B-3	19.0 - 19.27	Sch	CH	Parting dip; 70°
10	B-4	8.0 - 8.2	Sch	CH	Parting dip; 81.6°
4	B-4	20.2 - 20.45	Sch	CH	Banded, greenish white
3	B-5	4.1 - 4.3	C-S	CH	Banded structure
13	B-5	28.2 - 28.45	Sch	CH	Banded structure
12	B-8	26 - 26.2	Sch	CH	Parting dip; 67.6°
2	B-9	7.3 - 7.55	Qz	CM	——
11	B-10	6.15 - 6.4	Gr	B	Non-parting
7	B-10	14.4 - 14.65	Gr	B	Parting dip; 72.5°

Note: Qz: Quartzite
C-S: Cale-silicate
Sch: Schist
Gr: Schistose granite

Test No.	Gs (t/m^3)	w (%)	s (kg/cm^2)	E50 (kg/cm^2)	Abrasion (%)
1	2.63	0.352	416	57,750	
8	2.63	0.15	909	119,579	
6	2.68	0.466	260	65,075	
9	2.92	0.65	118	32,750	
5	2.65	0.507	130	108,583	
10	2.68	0.465	222	65,411	
4	2.74	0.192	547	91,100	26.0
3	2.68	0.916	335	49,265	
13	2.64	1.09	94	29,312	
12	2.69	0.441	204	63,594	
2	2.60	0.755	282	74,210	
11	2.67	0.709	654	88,378	
7	2.65	0.33	555	115,666	

Note: Gs: Specific gravity
w: Water absorption ratio
s: Unconfined compression strength
E50: Modulus of elasticity

1.4.5 Hand auger boring

Around the dam axis, hand auger borings were conducted by RID. Most of boring could not penetrate the depth more than 1.0 m except several spots where the river deposits are distributed along the river course. Penetration depth is summarized as follows:

AH-1	0.9 m	AH-10	0.4 m	AH-19	0.7 m
AH-2	0.4 m	AH-11	1.4 m	AH-20	0.5 m
AH-3	3.0 m	AH-12	0.5 m	AH-21	2.4 m
AH-4	0.65 m	AH-13	0.5 m	AH-22	1.2 m
AH-5	0.85 m	AH-14	0.5 m	AH-23	0.4 m
AH-6	0.65 m	AH-15	0.6 m	AH-24	1.3 m
AH-7	0.65 m	AH-16	1.4 m	AH-25	2.3 m
AH-8	0.50 m	AH-17	1.0 m	AH-26	1.1 m
AH-9	1.0 m	AH-18	0.6 m	AH-29	1.4 m

2. EMBANKMENT MATERIALS

2.1 Investigation and Laboratory Tests

2.1.1 General

A soil mechanical investigations were carried out to clarify the characteristics of embankment materials. Nineteen test pits of 2 x 2 m were excavated, for a total depth of 37.7 m and samples were taken for laboratory soil mechanical tests. All these investigations and tests were operated by RID staff. Location of test pits are shown in Fig. II-2. It is summarized as follows:

(1) Test pit excavation

No.	Location	Depth (m)	No.	Location	Depth (m)
1.	Right, downstream	2.8	11.	Right, downstream	1.4
2.	Right, downstream	2.3	12.	Right, downstream	1.8
3.	Right, downstream	2.9	13.	Left, downstream	1.3
4.	Left, upstream	3.6	14.	Left, downstream	1.0
5.	Left, upstream	3.0	15.	Left, downstream	1.3
6.	Right, upstream	3.0	16.	Right, downstream	1.8
7.	Right, upstream	3.6	17.	Right, downstream	1.5
8.	Right, downstream	1.0	18.	Right, downstream	1.4
9.	Right, downstream	Not operated	19.	Right, downstream	0.9
10.	Right, downstream	1.8	20.	Right, downstream	1.3
				Total	37.7

(2) Laboratory soil mechanical test

Test Item	Number of Samples	
	1st Stage	2nd Stage
1. Grain size analysis	30	28
2. Specific gravity test	14	28
3. Liquid limit test	30	28
4. Plastic limit test	30	28
5. Field moisture content	-	14
6. Compaction test	13	4
7. Tri-axial compression test	-	5
8. Consolidation test	-	4
9. Permeability test	2	11

Note: 1st stage: March 3, 1985 - May 29, 1985
2nd stage: July 22, 1985 - September, 1985

2.1.2 Borrow area and characteristics of soil

In the vicinity of damsite, deposited soil materials possible to utilize for embankment are classified roughly into three groups according to their location and characteristics.

First group is deposited about 2 km upstream of damsite within the proposed reservoir area and downstream right side of the river. Soils are decomposed granite residual soil and secondary transported talus deposit originated also from granite. These materials are classified into sandy clay (SC) and clayey sand (CS).

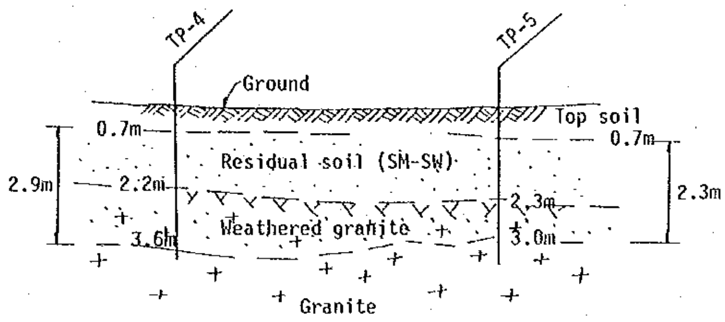
Second group is deposited at downstream left side of the river and consists of mainly decomposed schist. The soils are ranging between reddish silty cley (ML-MH) and soft weathered rock.

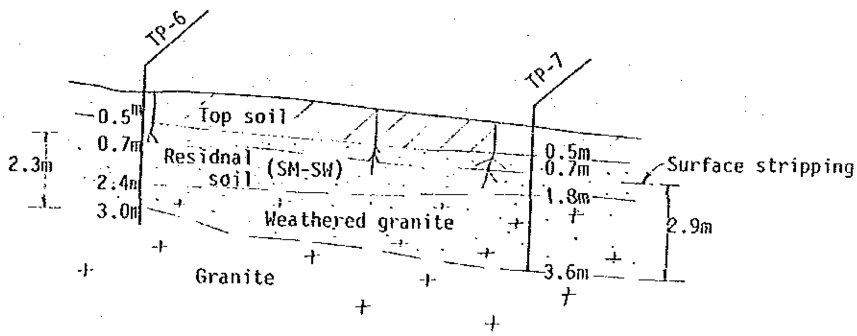
Third group is of diluvial terrace deposit found at about 6 km downstream from the damsite.

(1) Reservoir area upstream of damsite

Four test pits (TP4 to TP7) were excavated during the course of investigation on the moderate slope of granite base. The materials obtained from these test pits consist of large quantity of coarse quartz particles and are classified into sandy silt and well graded sand (SM-SW). Quartz particles are generally difficult for weathering by means of short time stockpiling. This was confirmed by the field investigation that property of excavated materials were not changed by stockpiling of more than 3 months. Based on the results of soil mechanical tests, it was concluded that these materials are not suitable for embankment of core zone but suitable for semi-pervious zone.

Surface geological profile explaining the order of soil layer is as follows:

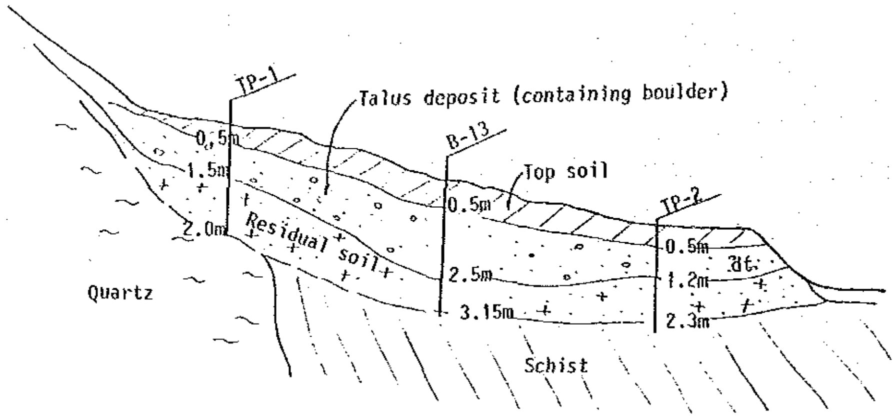


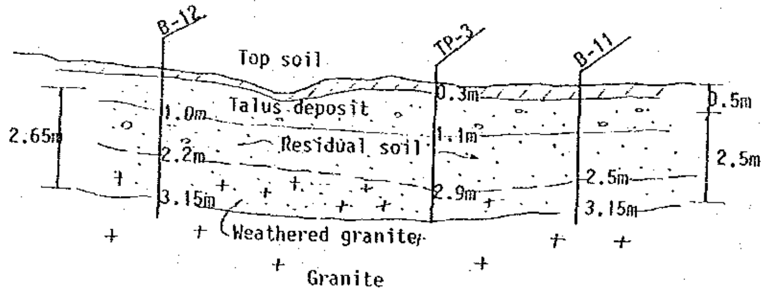


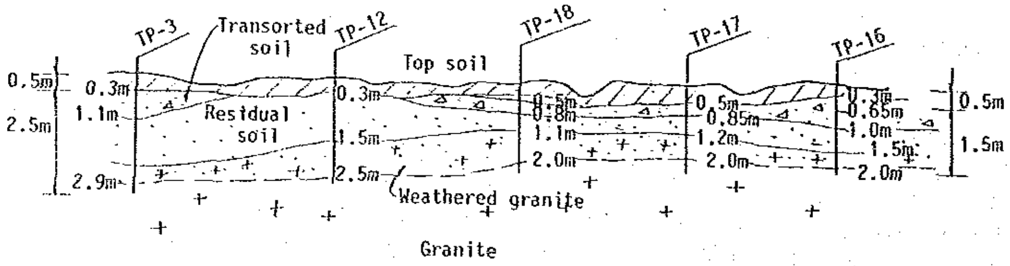
(2) Downstream at right side of river

In the area about 2 km downstream of damsite and right side of river, eight (8) test pits (TP-1 to 3 and TP-16 to 20) were excavated and 3 borings (B-11 to 13) were performed.

Materials deposited in this area are residual quartzite and schistose soils and residual granite soils. Residual of quartzite and schist materials found at TP-1 and TP-2 contain less feldspar but much amount of quartz particles, similar to those soils at upstream of damsite. Stockpiling will not effective for weathering of these soils. Residual granite soils found in test pits of TP-3, 12, 16, 17, 18 and boring holes of B-11 and B-12 contain much amount of feldsparthic materials with small to medium particle of quartz. Through the field investigation and laboratory tests, it was confirmed that these feldsparthic particles easily change soil mechanical properties through short time stockpiling and moisture control and become suitable for embankment of core zone. Geological profiles of this borrow area are derived from the test pits and boring investigations and summarized as follows:







(3) Downstream at left side of river

In this area, materials originated from schist and granite are covering the ground surface. Three test pits (TP-13, 14, 15) were excavated. Along the existing cart road, outcrops of granite is observed. From the test pits excavation, it was found that the deposit of residual material is less in quantity and clayey residual soil cover of schist original forms very thin layer. Consequently, it was considered these materials will not be suitable for embankment of core zone but suitable for semi-pervious zone.

(4) Diluvial plane

About 6 km downstream from damsite, diluvial deposit soil originated from granite forms a diluvial plane. This diluvial soils are judged to be suitable for core zone material but hauling distance is too long and it will need to construct new roads to the damsite. Accordingly, the diluvial plane will be placed as supplemental borrow area.

2.2 Material Characteristics

2.2.1 Impervious materials (core zone)

The residual soil materials deposited at the proposed borrow area at downstream of damsite at right side of the river consist of much amount of feldspar particles. These soils have characteristics to become plastic clayey soil from sandy soil by means of stockpiling which will accelerate moisture control and mixture of soil layers. This characteristic was also shown by the laboratory tests as follows:

Sample		Before Stockpiling			After Stockpiling		
TP-No.		LL (%)	PL (%)	PI	LL (%)	PL (%)	PI
TP-1	0 - 1.5 m	28.8	78.1	10.7	63.0	28.4	34.6
	1.5 - 2.8 m	53.0	21.1	31.8			
TP-2	0 - 1.2 m	NP	NP	NP	49.1	26.7	23.0
	1.2 - 2.3 m	25.8	16.7	9.1			
TP-3	0 - 1.1 m	30.1	20.6	9.5	59.0	27.9	31.1
	1.1 - 2.3 m	43.0	18.5	24.5			

Note: LL: Liquid limit
PL: Plastic limit
PI: Plastic index
NP: Non-plastic

Stockpiling is also effective to increase the content of fine particles of silt and clay which effect considerably on the improvement of permeability. In this study, silt and clay contents (Rf) in the residual soil changes as follows:

Before stockpiling	Rf = 8 - 22%
After stockpiling	Rf = 26 - 36%

Generally, the materials for embankment of core zone should have Rf value at more than 15% to ensure low permeability. This was also confirmed by permeability test. However, most of soil samples with low moisture content or low saturation ratio of less than 70% could not attain the permeability less than 1 x 10^{-6} cm/sec. From this characteristics, moisture control by water sprinkling will be required at stockpiling or at borrow area.

2.2.2 Semi-pervious materials

Samples of semi-pervious materials were obtained from TP-4, 5, 6 and 7. These samples are well graded fine to coarse sandy materials containing about 10% of fine particles of less than silt size. They belong to SM-SP in the unified soil classification. Specific gravity ranges from 2.64 to 2.68 and 2.66 as average. Consistency is non-plastic. Maximum dry density at compaction test was mostly above 2.0 t/m^3. Optimum moisture content (Wopt) is about 8% in spite of field moisture content at about 3%. Water sprinkling procedure will be required during construction to approve dense and constant quality.

Table II-1 RESULTS OF WATER PRESSURE TEST (1/2)

Boring No.	Depth (m)	Lugion Value	Pressure (kg/cm^2)	Remarks
B - 1	0.0 - 1.5	($9.54x10^{-3}$)	G	GWT=None
	3.0 - 8.0	20.2	1.4	
	8.0 - 13.0	16.9	2.45	
	13.0 - 18.0	20.6	2.45	
	18.0 - 23.0	14.4	2.45	
	23.0 - 28.0	0.2	5.6	
	28.0 - 33.0	0.0	6.65	
B - 2	0.0 - 1.5	($2.0x10^{-1}$)	G	GWT= 7.55 m
	3.6 - 5.5	($2.6x10^{-3}$)	G	
	5.5 - 6.5	($4.0x10^{-3}$)	G	
	6.5 - 7.5	($1.7x10^{-3}$)	G	
	7.5 - 8.1	($9.3x10^{-4}$)	G	
	9.0 - 14.0	1.9	3.0	
	14.0 - 19.0	0.0	4.0	
	19.0 - 24.0	0.0	5.0	
	24.0 - 29.0	0.5	6.0	
	29.0 - 34.0	0.5	7.0	
B - 3	13.0 - 16.0	1.4	3.15	GWT=Riverbed
	19.0 - 22.0	0.3	4.2	
	22.0 - 25.0	0.5	4.9	
	25.0 - 28.0	0.3	5.6	
	28.0 - 31.0	0.0	6.3	
	31.0 - 34.0	0.3	7.0	
	34.0 - 37.0	0.0	7.35	
	37.0 - 40.0	0.1	8.05	
	40.0 - 45.0	0.0	9.1	

GWT : Groundwater table

Lugion Value : ( ) expressed by coefficient of permeability (cm/s)

G : Gravitational head

Table II-1 RESULTS OF WATER PRESSURE TEST (2/2)

Boring No.	Depth (m)	Lugion Value	Pressure (kg/cm^2)	Remarks
B - 4	1.5 - 6.5	10.1	1.2	GWT=Riverbed
	6.5 - 11.5	1.3	2.0	
	11.5 - 16.5	5.6	3.0	
	16.5 - 21.5	0.8	4.0	
	21.5 - 26.5	0.2	5.0	
	26.5 - 31.5	0.8	6.0	
	31.5 - 36.5	0.0	7.0	
B - 5	5.0 - 10.0	12.6	2.0	GWT=5.60m
	10.0 - 15.0	1.5	3.0	
	15.0 - 20.0	0.2	4.0	
	20.0 - 25.0	1.2	5.0	
	25.0 - 30.0	2.4	6.0	
	30.0 - 35.0	2.7	7.0	
B - 6	5.0 - 10.0	46.6	2.0	GWT=None
	10.0 - 15.0	37.2	3.0	
	15.0 - 20.0	4.6	4.0	
	20.0 - 25.0	0.8	5.0	
	25.0 - 30.0	0.2	6.0	
B - 8	0.0 - 1.5	(2.7×10^{-4})	G	GWT=None
	1.5 - 2.5	(1.6×10^{-4})	G	
	2.5 - 3.5	(1.1×10^{-4})	G	
	3.5 - 4.5	0.0	G	
	6.0 - 11.0	22.9	2.0	
	11.0 - 16.0	0.0	3.0	
	16.0 - 21.0	0.0	4.0	
	21.0 - 26.0	0.2	5.0	
	26.0 - 31.0	0.7	6.0	

GWT : Groundwater table

Lugion Value : ( ) expressed by coefficient of permeability (cm/s)

G : Gravitational nead

Table II-2 SUMMARY OF SOIL LABORATORY TESTS (1/3)

Test Pit No.	Depth m	Cl.	Gradation %			Wn %	Gs	Consistency			Compaction Test		Specimen Condition	C-U Tri-axial Test		Permeability Test	Description
			Clay & Silt	Sand	Gravel			L.L.	P.L.	P.I.	γdmax g/cm³	Wopt %		C' kg/cm²	φ' degree	Kv cm/sec	
TP-1	0.0-1.5	SC	19	68	13		2.67	28.8	18.1	10.7	2.059	8.7					
"	1.5-2.8	SC	31	54	15		2.63	53.0	21.2	31.8	1.834	13.5					
TP-2	0.0-1.2	SM	15	69	16		2.67			NP	2.104	8.1					
"	1.2-2.3	SC	14	30	56		2.67	25.8	16.7	9.1	1.995	9.2					
TP-3	0.0-1.1	SC	21	75	4		2.67	30.1	20.6	9.5	1.980	10.5					
"	1.1-2.9	SW-SM	7	58	35		2.69	43.0	18.5	24.5	1.995	10.0					
TP-4	0.0-2.2	SP-SM	11	82	7		2.67			NP	2.026	8.5					
"	2.2-3.6	"	11	82	7		2.67			NP	1.975	9.5					
TP-5	0.0-2.3	SM	14	77	9		2.65			NP	-	-					
"	2.3-3.0	SP-SM	9	82	9		2.66			NP	-	-					
TP-6	0.0-2.4	SM	12	82	6		2.63			NP	2.020	8.6	EC=100% γdmax (Wopt)	0.30	40	$3.6x10^{-6}$	
													EC=100% γdmax x95 (Wopt)	0.30	36.5	-	
"	2.4-3.0	SP-SM	11	80	9		2.68			NP	-	-					
TP-7	0.0-1.8	SP-SM	11	79	10		2.65			NP	2.050	8.2					
"	1.8-3.6	SP-SM	9	81	10		2.64			NP	-	-					
TP-8		SC	27	73	0	6.0	2.63	42.4	24.3	18.1							
TP-9		SM	21	67	12	3.9	2.68	33.8	23.8	10.0							
TP-12			25	66	9	7.6	2.66	38.7	23.6	15.1							
TP-13			19	39	42	10.0	2.68	39.7	25.5	14.2							
TP-14			20	60	20	5.1	2.64	30.8	20.0	10.8							
TP-15		GP-GM	7	20	73	6.9	2.77	34.0	26.2	7.8							
TP-16		SM	41	58	1	7.3	2.62	63.0	29.7	33.3							

Cl. : Unified soil classification
Wn : Natural moisture content

Table II-2 SUMMARY OF SOIL LABORATORY TESTS (2/3)

Test Pit No.	Depth m	Cl.	Gradation %			Wn %	Gs	Consistency			Compaction Test		Specimen Condition	C-U Tri-axial Test		Permeability Test	Description
			Clay & Silt	Sand	Gravel			L.L.	P.L.	P.I.	γdmax g/cm³	Wopt %		C' kg/cm²	φ' degree	Kv cm/sec	
TP-17		SC	13	79	8	4.3	2.65	38.0	23.4	14.0							
TP-18		SM	22	39	39	7.0	2.66	35.6	26.5	9.1							
TP-19		SC	15	77	8	3.1	2.68	32.6	22.4	10.2							
TP-20		SC	12	80	8	6.5	2.64	29.9	21.9	8.0							
TP-2		SM	27	72	1		2.67	33.8	24.0	9.8	1.995	9.2	EC=200%	-	-	$5.2x10^{-8}$	Stockpiled for 2 weeks
													EC=100% γdmax (Wopt)	-	-	$1.3x10^{-7}$	"
													EC=100% γdmax x95(Wopt)	0.2	23.0	$1.0x10^{-8}$	"
													EC=100% γdmax x95 (Dry side)	-	-	$2.9x10^{-8}$	"
TP-3		SC	40	53	7		2.69	43.2	23.6	19.6	1.980	9.2					"
TP-8		SC	23	77	0		2.68	34.7	21.4	13.3							"
TP-10		SM	21	68	11		2.74			NP							"
TP-12		SM	28	58	14		2.69	42.3	27.0	15.3	1.900	11.5	EC=100% γdmax (Wopt)	-	-	$5.8x10^{-8}$	"
													EC=100% γdmax x95 (Wopt)	-	-	$4.2x10^{-5}$	"
													EC=100% γdmax x95 (Dry side)	0.13	32.5	$8.9x10^{-5}$	"
TP-13		GP-GM	9	18	73		2.73	42.0	26.4	15.6	1.865	12.0	EC=100% γdmax (Wopt)	-	-	$1.4x10^{-7}$	"
													EC=100% γdmax x95 (Wopt)	-	-	$1.5x10^{-4}$	"
													EC=100% γdmax x95 (Dry side)	0.15	33.5	$5.3x10^{-5}$	"
TP-14		SC	18	58	24		2.66	31.3	20.5	10.8							"
TP-15		SM	10	27	63		2.82	33.0	24.8	8.2							"
TP-16		SC	35	64	1		2.67	50.0	25.1	24.9							"
TP-17		SC	29	68	3		2.69	40.8	24.2	16.6							"
TP-18		SM	24	72	4		2.67	34.3	24.3	10.0							"

Cl. : Unified soil classification
Wn : Natural moisture content

Table II-2 SUMMARY OF SOIL LABORATORY TESTS (3/3)

Test Pit No.	Depth m	Cl.	Gradation %			Wn %	Gs	Consistency			Compaction Test		Specimen Condition	C-U Tri-axial Test		Permeability Test	Description
			Clay & Silt	Sand	Gravel			L.L.	P.L.	P.I.	γdmax g/cm³	Wopt %		C' kg/cm²	φ' degree	Kv cm/sec	
TP-19		SM	38	55	7		2.73	38.3	25.3	13.0							Stockpiled for 2 weeks
TP-20		SC	11	56	33		2.73	28.7	20.7	8.0							"
TP-21		SC	19	75	6		2.67	30.7	22.0	8.7							"
TP-22		SC (Upper)	44	53	3		2.70	32.3	20.9	11.4							"
TP-22		SC (Lower)	17	49	34		2.75	34.0	23.2	10.8							"
TP-1		SC	25	43	32	9.4	2.63	63.0	28.4	34.6							Stockpiled for 4 days
TP-2		SC	32	63	5	15.6	2.60	49.7	26.7	23.0							"
TP-3		SC	21	59	20	12.9	2.65	59.0	27.9	31.1							"
AH-2	0.0-0.4	SP	4	95	1					NP							
AH-3	0.0-0.9	SP-GM	51	48	1					NP							
"	0.9-3.0	ML	11	88	1					NP							
AH-5	0-0.85	SM-SC	42	53	5			24.4	18.2	6.2							
AH-6	0-0.65	SM	15	39	46					NP							
AH-9	0-1.0	SM	17	72	11					NP							
AH-10	0-0.4	SM	27	53	20					NP							
AH-15	0-0.6	SP	1	82	17					NP							
AH-16	0-0.4	SM	41	59	0					NP							
AH-17	0-1.0	SW	0	89	11					NP							
AH-18	0-0.6	SP	1	97	2					NP							
AH-23	0-0.4	SM	18	56	26					NP							
AH-24	0-1.3	SM	21	73	6					NP							
AH-25	0-1.75	SM	37	63	0												
AH-25	1.75-2.3	SM	29	70	1												
AH-26	0-1.1	SM	27	73	0												

Era	Period	Symbol	Geology	Structure	Rock	Distribution
Cenozoic	Recent	dt Rd	Talus deposit Alluvial deposit	Level	Gravel & sand	Along river course
	Pleistocene	Td	Terrace deposit	Gentle slope to east	Sand & sandy silt	Hill slope
Mesozoic	Jurassic	Mz	KHAO CHONKAN Formation	NNW-SSE, 50 E	Sandstone, Shale conglomerate	KHAO CHONKAN Mountain
		Gr	Granite group	-	Granite, Granite gneiss Schistose Gr, Diorite	Reservoir & Western basin
Palaeozoic	Cambrian	E	Huai-wai quartzite	-	Quartzite, Phyllite, Schist	Higher elevation of western basin
Proterozoic	Precambrian	PE	Uthai Thani complex	N - S, 60-90 S	Quartzite, Schist, Calc-silicate	Damsite

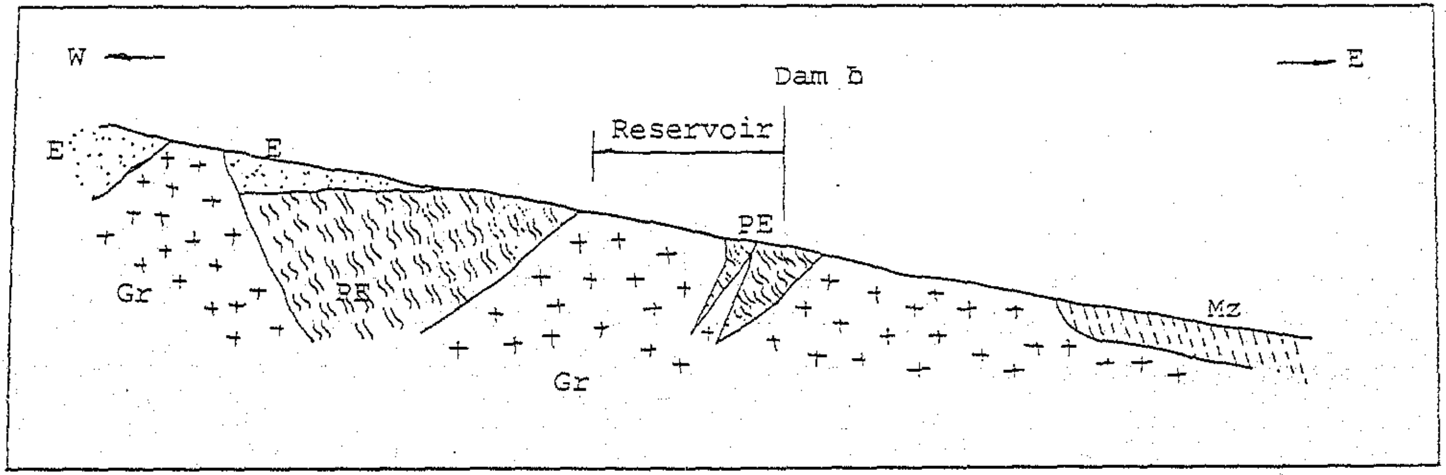


Fig. II-1 Geologic Chronology

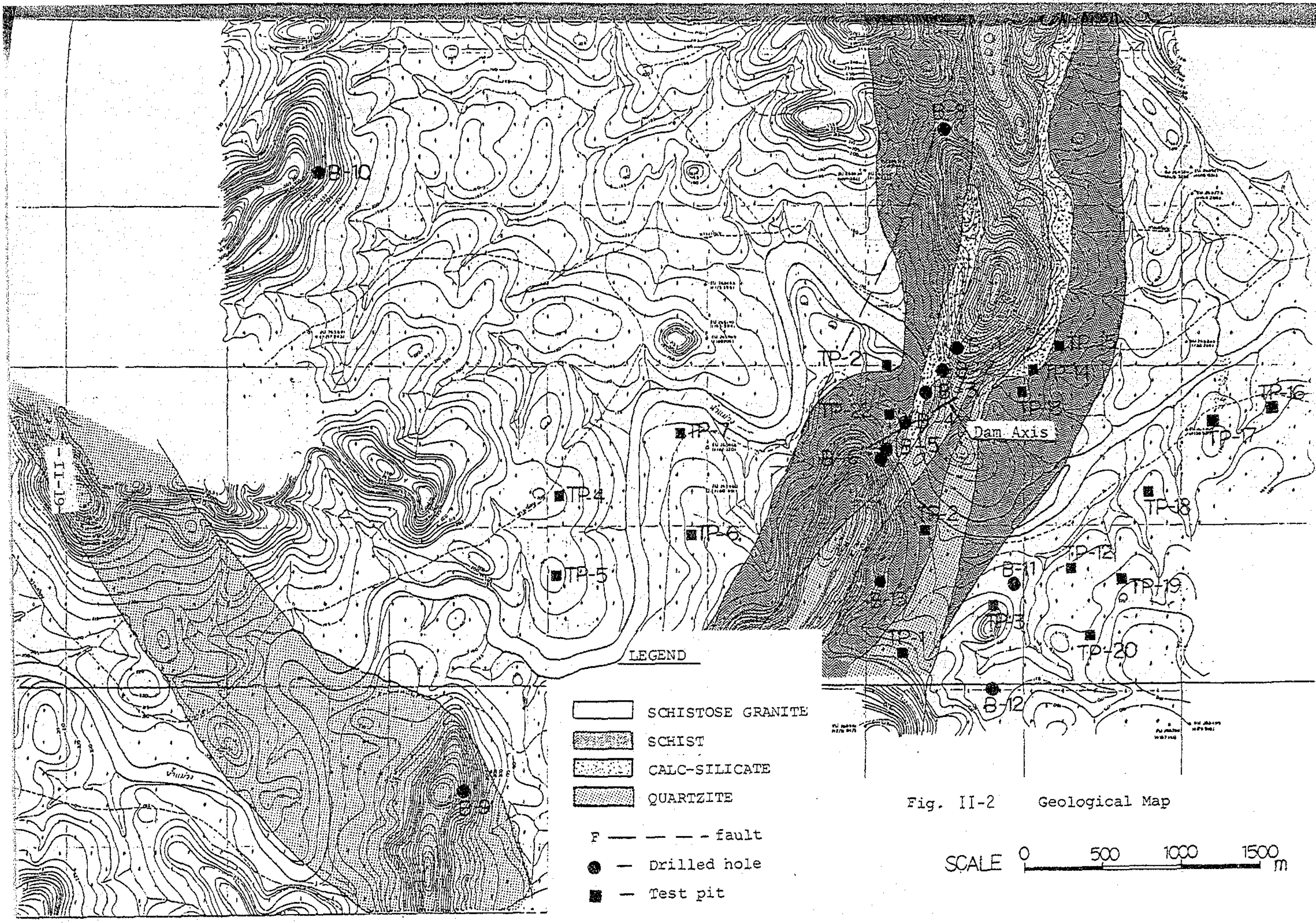
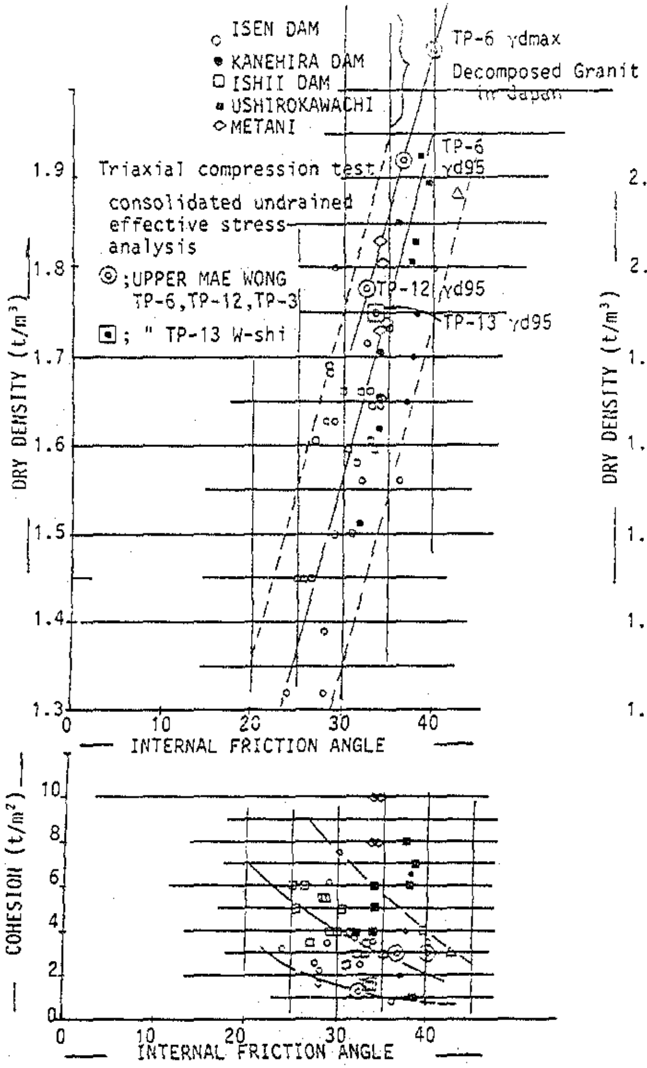
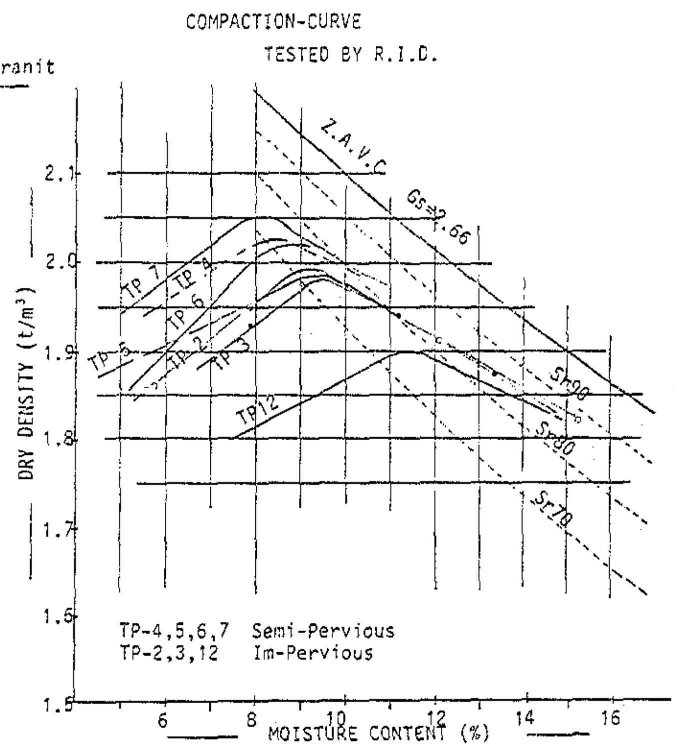
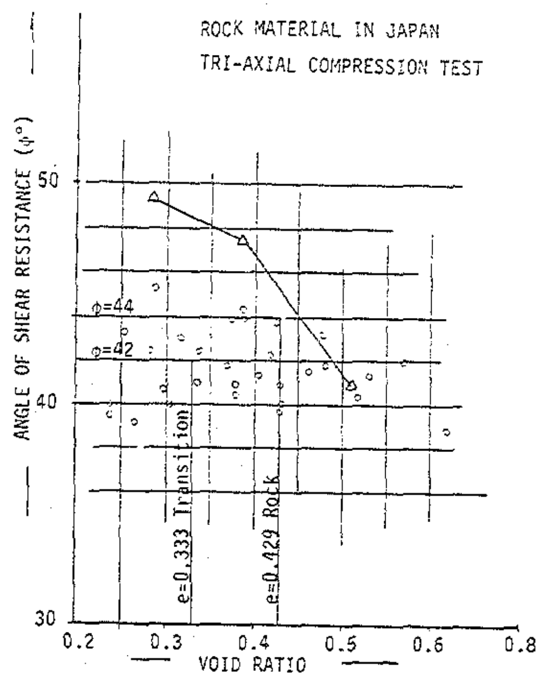


Fig. II-2 Geological Map







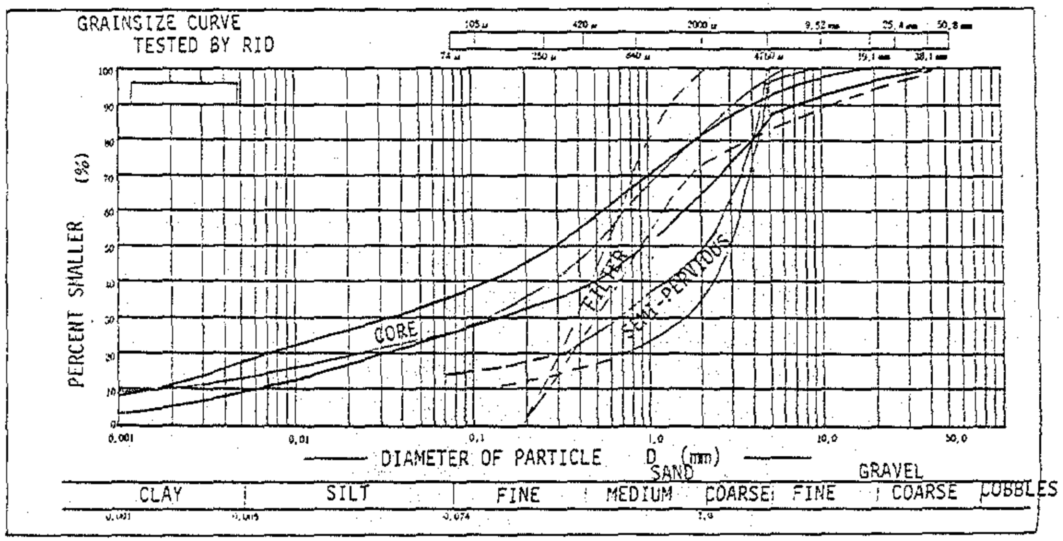


Fig. II-3 Results of Soil Mechanical Test